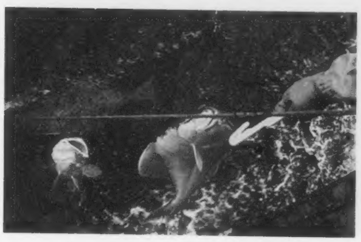
Marine Fisheries REVIEW

Vol. 66, No. 2
2004

United States Department of Commerce



Bycatch

Marine Fisheries REVIEW

W. L. Hobart, Editor
J. A. Strader, Managing Editor

On the cover: Three examples of target species and bycatch. Photo credits: top, International Pacific Halibut Commission; lower left and right, Alaska Groundfish Observer Program.

Articles — *66(2), 2004*

U.S. DEPARTMENT OF COMMERCE
Carlos M. Gutierrez, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Vice Admiral
Conrad C. Lautenbacher, Jr.,
U.S. Navy (Ret.), Under Secretary
for Oceans and Atmosphere

National Marine Fisheries Service
William T. Hogarth
Assistant Administrator for Fisheries

The *Marine Fisheries Review* (ISSN 0090-1830) is published quarterly by the Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., BIN C15700, Seattle, WA 98115. Annual subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. The annual subscription price is $21.00 domestic, $29.40 foreign. Single copies are $12.00 domestic, $16.80 foreign. For new subscriptions write: New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

POSTMASTER: Send address changes for subscriptions for this journal to: *Marine Fisheries Review*, c/o Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. This issue, volume 66 number 2, was printed and distributed in September 2005.

This publication is available online at
http://spo.nwr.noaa.gov/mcontent.htm

The National Marine Fisheries Service's National Bycatch Strategy

LEE R. BENAKA and TANYA J. DOBRZYNSKI

Introduction

Minimizing bycatch has become an increasingly important priority for the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) over the past several years and remains a central fishery management challenge for the agency. Reduction of marine fisheries bycatch is central to several of the NMFS's governing statutes, including the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), the Endangered Species Act (ESA), and the Marine Mammal Protection Act (MMPA).

Lee R. Benaka is with the Office of Sustainable Fisheries, National Marine Fisheries Service (NMFS), NOAA, 1315 East-West Highway, Room 13437, Silver Spring, MD 20910, and Tanya J. Dobrzynski is with the NMFS Office of Protected Resources, 1315 East-West Highway, Room 13758, Silver Spring, MD 20910.

ABSTRACT—The National Marine Fisheries Service (NMFS) launched its National Bycatch Strategy (NBS) in March 2003 in response to the continued fisheries management challenge posed by fisheries bycatch. NMFS has several strong mandates for fish and protected species bycatch reduction, including the Magnuson-Stevens Fishery Conservation and Management Act, the Endangered Species Act, and the Marine Mammal Protection Act. Despite efforts to address bycatch during the 1990's, NMFS was petitioned in 2002 to count, cap, and control bycatch. The NBS initiated as part of NMFS's response to the petition for rulemaking contained six components: 1) assess bycatch progress, 2) develop an approach to standardized bycatch reporting methodology, 3) develop bycatch implementation plans, 4) undertake education and outreach, 5) develop new international approaches to bycatch, and 6) identify new funding requirements. The definition of bycatch for the purposes of the NBS proved to be a contentious issue for NMFS, but steady progress is being made by the agency and its partners to minimize bycatch to the extent practicable.

In recent years, NMFS's constituents have shined a bright spotlight on the issue of bycatch and the agency's handling of its various mandates to monitor and reduce bycatch. In March 2003, NMFS launched its National Bycatch Strategy (NBS), which was aimed at building upon previous efforts to address bycatch to forge new ground in the areas of bycatch monitoring and reduction. This article reviews the major components of the NBS and discusses its progress to date.

Mandates for Bycatch Reduction

The NMFS has several strong mandates for fish and protected species bycatch reduction, including the MSFCMA, ESA, and MMPA. These mandates are discussed in the following subsections.

Magnuson-Stevens Act

In 1996, Congress amended the Magnuson Fishery Conservation and Management Act (becoming the MSFCMA) in part to define the term "bycatch" as well as to require that bycatch be minimized to the extent practicable. Bycatch, as defined by the MSFCMA (16 U.S.C. § 1802 (2)), "means fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards. The term does not include fish released alive under a recreational catch and release fishery management program." "Economic discards" are "fish which are the target of a fishery, but which are not retained because of an undesirable size, sex, or quality, or other economic reason." The term "regulatory discards" means "fish harvested in a fishery which fishermen are required by regulation to discard whenever caught, or are required by regulation to retain but not sell." Note that because the definition of "fish" refers to "finfish, mollusks, crustaceans, and all other living forms of animal and plant life other than marine mammals and birds," the bycatch reduction requirements in the MSFCMA do not apply to all living marine resources under NMFS's jurisdiction.

National standard 9 of the MSFCMA requires that "conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch" (16 U.S.C. § 1851(9)). Sec. 303 of the MSFCMA expands on this requirement somewhat, stating that fishery management plans are required to "establish a standardized reporting methodology to assess the amount and type of bycatch occurring in the fishery, and include conservation and management measures that, to the extent practicable and in the following priority (A) minimize bycatch and (B) minimize the mortality of bycatch which cannot be avoided" (16 U.S.C. § 1853(11)).

Endangered Species Act

The ESA requires the Federal government to protect and conserve species and populations that are endangered, or threatened with extinction, and to conserve the ecosystems on which these species depend. Some of these threatened and endangered species, including certain species of sea turtles (for example, the leatherback turtle, *Dermochelys coriacea*), Pacific salmon (for example,

some evolutionarily significant units of chum salmon, *Oncorhynchus keta*, and marine mammals (for example, the northern right whale, *Eubalaena glacialis*), are captured or taken as bycatch in the nation's fisheries. The bycatch reduction requirements of the ESA follow from Section 9(a)(1)(B) and 9(a)(1)(C) of the ESA, which prohibit the take of endangered species within the United States or the territorial sea of the United States, and on the high seas, respectively. "Take" is defined by the ESA as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct" (16 U.S.C. 1536(18)). ESA Sections 4, 6, 7, and 10 provide mechanisms for the limited take of ESA-listed species. Of particular relevance for fisheries bycatch is Section 7, which provides that "Each Federal agency shall...insure that any action authorized, funded, or carried out by such agency … is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species …"(16 U.S.C. §1536(a)(2)). For example, Section 7 consultations and resulting biological opinions and reasonable and prudent alternatives have resulted in fishery regulations to prevent bycatch of endangered and threatened sea turtles in the Atlantic and Pacific Oceans.

Several seabird species, such as the marbled murrelet, *Brachyramphus marmoratus*, and short-tailed albatross, *Phoebastria albatrus* (excluding U.S. populations), are protected under the ESA as well. In cooperation with the Department of the Interior's U.S. Fish and Wildlife Service, the NMFS monitors and reports the bycatch of these and other seabirds. Additionally, international conventions and treaties also play a significant role in the national approach to bycatch management. For example, the Food and Agriculture Organization of the United Nations, Committee on Fisheries, developed the International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries. This plan is being implemented by NMFS and other fishing countries via corresponding National Plans of Action.

Marine Mammal Protection Act

The MMPA seeks to maintain populations of marine mammals at optimum sustainable population levels, principally by regulating the take of marine mammals. Under the MMPA, "take" is defined as "to harass, hurt, capture, or kill, or attempt to harass, hurt, capture, or kill any marine mammal." This includes fishing-related mortality and serious injury. Although the MMPA prohibits the take of marine mammals, it provides exceptions to the prohibition for incidental mortality and serious injury in the process of commercial fishing activities. Section 118 of the MMPA requires that NMFS classify each U.S. fishery according to whether it has a frequent (Category I), occasional (Category II), or remote (Category III) likelihood of incidental mortality and serious injury to marine mammals. It also establishes a process for take reduction teams to develop take reduction plans (TRP's) for fisheries that result in frequent or occasional incidental mortality or serious injury of "strategic" marine mammal stocks.[1] Participants in Category I or II fisheries are required to register with NMFS, take on board an observer if requested by NMFS to do so, and to comply with all applicable TRP regulations. All fishermen, including those participating in Category III fisheries, are required to report the incidental mortality and serious injury of a marine mammal should it occur. Take reduction plans currently are in effect for the harbor porpoise, *Phocoena phocoena*, in the Mid Atlantic and Gulf of Maine regions; large whales (*Eubalaena glacialis*, *Megaptera novaenangliae*, and *Balaenoptera physalis*) in the Atlantic; and the pilot whale, *Globicephala macrorhynchus*; pygmy sperm whale, *Kogia breviceps*; sperm whale, *Physeter macrocephalus*; humpback whale, *Megaptera novaeanliae*; and beaked whales (*Berardius bairdii*, *Mesoplodon* spp., *Ziphius cavirostris*) in the Pacific. A TRP for the coastal bottlenose dolphin, *Tursiops truncatus*, in the western North Atlantic is near completion.

[1]The term "strategic stock" means a marine mammal stock 1) for which the level of direct human-caused mortality exceeds the potential biological removal level, 2) that, based on the best available scientific information, is declining and is likely to be listed as a threatened species under the ESA of 1973 within the foreseeable future, or 3) that is listed as a threatened species or endangered species under the ESA of 1973, or is designated as depleted under the MMPA (16 U.S.C. 1362(19)).

Efforts to Evaluate and Address Bycatch

Following the enactment of the MSFCMA in 1996, the NMFS established a national team that produced the 1998 report "Managing the Nation's Bycatch" (NMFS, 1998). This comprehensive report identifies a number of high-priority needs in the area of gear technology and selectivity and fish behavior research. "Managing the Nation's Bycatch" adopts a broad definition of bycatch that takes into consideration all of NMFS's bycatch reduction responsibilities under the MSFCMA, ESA, and MMPA. The report definies bycatch as, "Discarded catch of any living resource plus retained incidental catch and unobserved mortality due to a direct encounter with fishing gear."

Seven national objectives are listed in the report as supporting achievement of the NMFS's national bycatch goal which is: "to implement conservation and management measures for living marine resources that will minimize, to the extent practicable, bycatch and the mortality of bycatch that cannot be avoided." These seven objectives include:

1) Determine the magnitude of bycatch,
2) Determine the population, ecosystem, social, and economic impacts,
3) Determine whether current conservation and management measures minimize bycatch,
4) Implement and monitor the preferred alternative,
5) Improve communications on bycatch issues,
6) Improve the effectiveness of external partnerships, and
7) Coordinate NMFS activities to effectively implement the bycatch plan.

The seven objectives are broken down into 22 individual strategies consisting

of 69 individual, substantive components. The report also listed a series of regional recommendations.

During the mid 1990's, at least 10 bycatch workshops were convened around the country (some of which resulted in proceedings volumes (Warren, 1994; Castro et al., 1996; University of Alaska Sea Grant Program, 1996)) to address the bycatch problem. NMFS bycatch reduction and minimization efforts continued through various management actions and policy activities after the publication of "Managing the Nation's Bycatch" and the flurry of workshops and meetings during the mid 1990's, but NMFS did not publish a follow-up to the 1998 report or actively organize or sponsor many high-profile bycatch workshops or fora in the years following the 1998 report. The lack of any sort of institutional "feedback loop" regarding the NMFS's progress in implementing the objectives in "Managing the Nation's Bycatch" made it impossible for the agency to systematically assess how effectively it had been reducing bycatch.

Petition for Bycatch Rulemaking

On 28 February 2002, Oceana, a nongovernmental environmental organization, petitioned the U.S. Department of Commerce to promulgate immediately a rule to establish a program to count, cap, and control bycatch in U.S. fisheries. The Oceana petition asserted that NMFS was not complying with its statutory obligations to monitor and minimize bycatch under the MSFCMA, ESA, and MMPA. The petition sought a regulatory program that included a workplan for observer coverage sufficient to provide statistically reliable bycatch estimates in all fisheries, the incorporation of bycatch estimates into restrictions on fishing, the placing of limits on directed catch and bycatch in each fishery with provision for closure upon attainment of either limit, and bycatch assessment and reduction plans as a requirement for all commercial and recreational fisheries. The NMFS published a notice of receipt of petition for rulemaking in the 18 April 2002 issue of the Federal Register (USDOC, 2003a) and invited public comments. In response, NMFS received 31 letters from different interest groups including regional fishery management councils, the Commonwealth of the Northern Mariana Islands, various commercial fishermen and fisheries organizations, environmental groups, and other interested individuals. Also, NMFS received tens of thousands of letters of similar content and petitions from interested members of the general public.

In its response to the petition, on 11 March 2003, NMFS published in the Federal Register (USDOC, 2003b) its decision not to initiate rulemaking immediately but instead to update and renew its commitment to a National Bycatch Strategy, which might eventually result in rulemaking for some fisheries. After carefully considering all public comment, the Assistant Administrator for Fisheries determined that the four-part program requested by the petition did not warrant specific rulemaking at this time. The NMFS recognized that the agency must continue to address bycatch in many domestic and international fisheries. However, given the diverse nature of U.S. fisheries (including gear type and deployment, fishing conditions, and other factors) and ongoing bycatch reduction initiatives, NMFS did not feel that global/national rulemaking as requested by Oceana was appropriate. Instead, NMFS emphasized the need for a regional approach working through the existing regulatory processes of the appropriate legal authorities and committed to continuing to work with regional fishery management councils (FMC's), regional fishery management organizations, states, and other partners and constituents to address bycatch and implement the agency's new strategy to combat bycatch both domestically and worldwide.

National Bycatch Strategy

The 11 March 2003, Federal Register notice responding to the Oceana petition outlined the agency's new National Bycatch Strategy. The Strategy includes six components that are described in more detail in the following subsections:

1) Assess progress toward meeting the national bycatch goal, its supporting objectives and strategies, and regional recommendations (as set forth in "Managing the Nation's Bycatch") which includes meeting the bycatch reduction requirements of relevant statutes, including national standard 9 of the MSFCMA, Section 118 of the MMPA, and the take prohibitions of the ESA.
2) Develop a national approach to a standardized bycatch reporting methodology.
3) Implement the national bycatch goal through regional implementation plans.
4) Undertake education and outreach involving cooperative efforts, at the regional level (and other levels as appropriate), by fishery managers, scientists, fishermen, and other stakeholders to develop effective and efficient methods for reducing bycatch.
5) Utilize existing partnerships and develop new international approaches to reducing bycatch of living marine resources including fish stocks, sea turtles, marine mammals, and migratory birds, where appropriate.
6) Identify new funding requirements to effectively support the NMFS National Bycatch Strategy on an ongoing basis.

Assessing Bycatch Progress

Shortly after publication of the National Bycatch Strategy, NMFS formed six regional bycatch teams (Northeast, Southeast, Southwest, Northwest, Alaska, and Pacific Islands) and one for the Atlantic Highly Migratory Species (HMS) Division within the NMFS Office of Sustainable Fisheries. These teams typically were comprised of managers, scientists, and observer program representatives, although one team included staff from regional FMC's, a marine fisheries commission, and a Sea Grant program. The teams were requested to assess their region's progress toward implementation of the objectives, strategies, and regional recommendations published in the 1998 report "Managing the Nation's Bycatch." For each of the 18 bycatch strategies (see below) described in "Managing the Nation's Bycatch," the

teams were asked to rate the degree to which their region had responded overall (rather than on a fishery-by-fishery basis) on a scale of 1 to 5:

1 = We have not been able to do anything at all with this element.
2 = We have attempted to address this element but have had limited success.
3 = We have addressed this element with some success, but we think much more could be done.
4 = We have done a lot to successfully address this element, but we could probably do a few more things.
5 = We have successfully addressed this element and can't think of a lot more that we could do.

Based on their responses, the teams were asked to provide reasons why the strategies had not been addressed fully or examples of how the strategies had been successfully addressed. In addition to the 18 strategies, the teams were asked to rate their responses to the various region-specific recommendations that were contained in "Managing the Nation's Bycatch." The 18 strategies, along with scores averaged over the six Regions and the Atlantic HMS Division, are listed below:

1) Review and, where necessary, improve collection methods, data sources, and applications of data to determine the magnitude of bycatch–3.3
2) Standardize the collection of bycatch data–3.0
3) Identify the type and quality of the information that currently exists–2.9
4) Establish research and management priorities on a fishery-by-fishery basis–3.4
5) Develop a fully integrated data collection system which includes biological, economic, and social information–2.6
6) Identify ecosystem-wide issues that can be addressed through a well-coordinated research program–2.8
7) Assess the impacts of bycatch–2.4
8) Evaluate current management measures–3.2
9) If existing measures do not adequately address defined management goals, develop, evaluate, and prioritize potential alternatives–3.4
10) Develop an implementation plan based upon a preferred alternative that includes monitoring and enforcement measures–3.4
11) Expand the capacity of individual fishing operations to reduce bycatch–3.1
12) Ensure coordination with domestic and international organizations–3.1
13) Implement monitoring systems–3.6
14) Implement an enforcement and compliance system–3.3
15) Identify outreach contacts for the exchange of bycatch-related information–3.1
16) Provide accurate and timely information on bycatch-related information issues, regulations, and activities–3.8
17) Establish partnerships to prepare and distribute bycatch information–2.9
18) Create opportunities for partner involvement in planning and monitoring bycatch reduction–3.3

The assessment also asked the regions and Atlantic HMS Division, on a fishery-by-fishery basis, to describe ways (if any) that the fishery could be strengthened in relation to the bycatch-related requirements of the MSFCMA, ESA, MMPA, and National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries. Information provided in response to the various questions in the assessment form was to support the creation of regional implementation plans in the third part of the National Bycatch Strategy.

Developing an Approach to Standardized Bycatch Reporting Methodology

Following the publication of the National Bycatch Strategy, a National Working Group on Bycatch (Working Group) was formed to, among other things, accomplish the following goals:

1) Make recommendations on the applicability of methods other than observer programs (e.g. video monitoring) for estimating the amount of bycatch.
2) Recommend standards of precision to be achieved for bycatch estimates.
3) Recommend criteria for identifying "vulnerability" of bycatch species to adverse impacts.

The Working Group submitted a draft report to the NOAA Assistant Administrator for Fisheries in July 2003, which was reviewed by NMFS's Regional Offices and Science Centers. The final report, "Evaluating Bycatch: A National Approach to Standardized Bycatch Monitoring Programs" (Evaluating Bycatch) (NMFS, 2004), recommends the following precision goals for estimates of bycatch, which are defined in terms of the coefficient of variation (CV) of each estimate:

1) Protected Species–For marine mammals and other protected species, including seabirds and sea turtles, the recommended precision goal is a 20–30% CV for estimates of bycatch for each species/stock taken by a fishery.
2) Fishery Resources–For fishery resources, excluding protected species, caught as bycatch in a fishery, the recommended precision goal is a 20–30% CV for estimates of total discards (aggregated over all species) for the fishery; or if total catch cannot be divided into discards and retained catch then the recommended goal for estimates of total catch is a CV of 20–30%.

However, "Evaluating Bycatch" also lists several caveats to the preceding precision goals, such as, that the goals may in some instances exceed minimum statutory requirements, that there are intermediate steps in increasing precision that may not immediately achieve goals but that represent progress nonetheless, and that there are circumstances in which higher levels of precision may be desired.

"Evaluating Bycatch" also includes an evaluation of over 80 fisheries na-

tionwide for bycatch monitoring. These fisheries are classified into one of five categories: no at-sea sampling program (none), baseline, pilot, developing, and mature. Table 1 provides definitions of these categories.

Additionally, all of these fisheries are rated as to their vulnerability (High, Moderate, or Low) to bycatch of fishery resources, marine mammals, and other protected species including seabirds and sea turtles. Of these fisheries, 5% have a "mature" observation program, 20% are "developing" programs (25% were either mature or developing), 10% have a "pilot" program, 29% have a "baseline" program, and 37% did not have a program, "none." Thirty-one percent of these fisheries are rated "High" for bycatch vulnerability of one or more of the three resource types: fishery resources, marine mammals, or other protected species (thus, 69% are rated "Moderate" or "Low" for all three resources); 6% of these fisheries are rated "High" for bycatch of one or more of the three resource types and are recommended for establishment of baseline or pilot observation programs.

"Evaluating Bycatch" also establishes three NMFS standardized bycatch reporting methodology (SBRM) objectives, keeping in mind that the MSFCMA requires an SBRM for each fishery management plan:

1) The development and documentation of an effective and efficient SBRM for each federally managed fishery, other state fisheries that take ESA-listed species that are under NMFS jurisdiction, and each MMPA Category I and II fishery, where the documentation of an SBRM includes the responsibilities of each entity involved in collecting and using data to estimate bycatch and total catch, as well as well-defined goals and objectives with associated performance criteria.
2) The periodic review of the SBRM for each of these fisheries.
3) The development of more effective and efficient methods, including electronic monitoring, for estimating bycatch or total catch.

Table 1.—Developmental stages for observation programs.

Observer Program Level	Definition
None	No systematic program exists for bycatch data collection
Baseline	An initial effort including at-sea monitoring to assess whether a systematic program is needed to estimate bycatch is completed.
Pilot	An initial at-sea monitoring program that obtains information from relevant strata (time, area, gear) for design of a systematic program to estimate bycatch with the ability to calculate variance estimates has been done.
Developing	A program in which an established stratification design has been implemented and alternative allocation schemes are being evaluated to optimize sample allocations by strata to achieve the recommended goals of precision of bycatch estimates for the major species of concern.
Mature	A program in which some form of an optimal sampling allocation scheme has been implemented. The program is flexible enough to achieve the recommended goals of precision of bycatch estimates for the major species of concern considering changes in the fishery over time.

To assist in meeting these objectives, "Evaluating Bycatch" establishes the following protocol for SBRM's:

1) Deploy at-sea observers in most cases as part of the preferred method for collecting bycatch data due to the effectiveness of at-sea observer programs.
2) Use other at-sea observation technologies (e.g. electronic monitoring) as appropriate to complement observer programs.
3) Use the appropriate sampling design as determined by the objectives of and the level and sources of funding for the observer program and other monitoring programs, where the objectives include providing a scientific and statistically valid basis for estimating bycatch or total catch.
4) Use the appropriate models for combining observer data with effort, landings, and/or other data to obtain accurate estimates of total bycatch or total catch.
5) Use appropriate methods to identify and decrease sources of bias.
6) Address the goal of achieving recommended levels of precision (20–30% *CV*) in estimating bycatch from observer data.
7) Adhere to standards established by NMFS to ensure the integrity and quality of the data collected in NMFS-approved observer programs, other data that are used in estimating bycatch or total catch, and the resulting estimates of bycatch or total catch.
8) Where appropriate, use other monitoring methods for estimating bycatch (e.g. using data from experimental tows, fishery-independent survey data, data from electronic monitoring technology, strandings data, or self-reported data) instead of at-sea observers.
9) Emphasize outreach to industry and other constituents and encourage their participation in the development of SBRM goals, objectives, and implementation plans.

Developing Implementation Plans

In December 2003, the Regional and Atlantic HMS bycatch implementation teams submitted bycatch implementation plans to the NOAA Assistant Administrator for Fisheries. Based on guidance from the NMFS Office of Sustainable Fisheries, these plans were to include the following elements:

1) The plans must cover Fiscal Years (FY) 2004 and 2005.
2) Every item rated as 1 or 2 in the bycatch assessments must be addressed in the implementation plans.
3) The plans should include action items addressing:
   A) standardization and enhancement of bycatch reporting methodologies,
   B) prioritization of top research needs,
   C) possible new bycatch management measures that should be considered on a fishery-by-fishery basis, and
   D) enhancement of education and outreach efforts, including technology transfer.

The seven bycatch implementation plans submitted contained a variety of ambitious and innovative action items, including the following:

1) Reducing fishing capacity in the Gulf of Mexico shrimp fishery.
2) Determining the effects of removals by U.S. fishing vessels of adult and sub-adult leatherback and loggerhead turtles on the reproductive capacity of the respective populations in the Pacific Ocean.
3) Promoting the use of electronic logbooks to facilitate identification and correction of bias in estimating bycatch for unobserved vessels in the Alaska Region.
4) Integrating 2002–2003 West Coast Groundfish Observer Program (WCGOP) data into the groundfish bycatch model and revising non-trawl/fixed gear 2004 groundfish landings limits based on early-2004 analysis of 2002–2003 WCGOP data.
5) Studying animal behavior as it relates to development of gear to reduce bycatch in Northeast priority fisheries.
6) Identifying, developing, and implementing new logbook data elements for Pacific Islands fisheries to capture any long-term effects from modified fishing practices.
7) Evaluating Atlantic HMS Headboat mandatory observer coverage and baseline program.

The NOAA Assistant Administrator for Fisheries will work with the NMFS Regional Administrators and Office of Sustainable Fisheries throughout 2004 and 2005 to ensure that the action items contained in the bycatch implementation plans are carried out to the extent practicable.

Undertaking Education and Outreach

Prior to the March 2003 publication of the Federal Register notice (USDOC, 2003b) responding to the Oceana petition for rulemaking, NMFS created a bycatch website linked to its homepage. This website (http://www.nmfs.noaa.gov/bycatch.htm) has grown considerably since and is updated at least weekly with new information about recent regulatory actions affecting fisheries and protected resources bycatch, international activities, bycatch reports and data sets, and updates on the National Bycatch Strategy, including all of the bycatch implementation plans discussed above.

NMFS also sponsored a 3-day international bycatch symposium at the American Fisheries Society's 2003 annual meeting in Quebec City. The symposium featured presentations by scientists and managers from inside and outside NMFS, as well as Canadian researchers and commercial fishermen. The symposium included several presentations on bycatch management in longline fisheries as well as bycatch data collection and uses.

As mentioned above, the Regional and Atlantic HMS bycatch implementation plans were required to address education and outreach topics. As a result, the plans contain a variety of education and outreach initiatives, including bycatch workshops, skipper training, development of additional online resources, and distribution of species identification guides.

Developing New International Approaches

The fifth component of the National Bycatch Strategy calls for the utilization of existing partnerships and development of new international approaches to reduce bycatch of living marine resources including fish stocks, sea turtles, marine mammals, and migratory birds, where appropriate. The objectives identified in this component of the National Bycatch Strategy include examination of the following:

1) International approaches to reduce bycatch of living marine resources extending beyond U.S. waters;
2) International agreements for potential broadening and for progress in implementation; and
3) Regional fishery management organizations and other fora for effectiveness of bycatch provisions.

NMFS's International Bycatch Reduction Task Force, which includes members from the U.S. Department of State, has been identified as the lead body in ongoing efforts to achieve these goals.

The tasks being undertaken to implement the U.S. strategy for international bycatch reduction are broken up into two categories: 1) international sea turtle workshops, and 2) international communications relating to sea turtles, sharks, and seabirds. Task Force members and NMFS staff have been engaged in a number of activities in support of international sea turtle workshops recently. Such activities have included the following:

1) NMFS presented research results from sea turtle–fishing experiments with the Atlantic pelagic longline fleet at the Inter-American Tropical Tuna Commission Bycatch Working Group in January 2004 in Kobe, Japan.
2) NMFS sponsored a workshop in Costa Rica in February 2004 that focused on providing information on safe turtle release to participants from nations with longline fleets.
3) Beginning in March 2004, NMFS, in collaboration with several partners, provided hooks, dehookers, and technical assistance to Ecuador for the testing of circle hooks to reduce turtle catches.
4) NMFS staff conducted longline mitigation training and workshops in Peru in June 2004.
5) NMFS sponsored workshops in August 2004 in Panama and Guatemala on the use of turtle dehookers and safe handling and release techniques.

Task Force members also have participated in the drafting and transmission of several diplomatic cables to flag states with significant longline fleets (and Taiwan):

1) A diplomatic demarche (cable) relating to sea turtles was sent that emphasized the international nature of the sea turtle bycatch problem in longline fisheries, described steps that the United States is taking to address it, and requested that recipients

provide information relative to sea turtle bycatch in longline fisheries.

2) A diplomatic demarche was sent to flag states with significant longline fleets (and Taiwan) that requested information on the status of implementing the Food and Agriculture Organization (FAO) International Plan of Action (IPOA) Relating to the Conservation and Management of Sharks.
3) A diplomatic demarche was sent to flag states with significant longline fleets (and Taiwan) that requested information on the status of implementing the FAO IPOA's for Seabirds.

Identifying New Funding Requirements

The NMFS National Bycatch Strategy encompasses a wide variety of new initiatives, both regional and national, over FY 2004 and 2005 and beyond. These initiatives include innovations in fishing gear, efforts to increase the understanding of fish and protected species behavior, bycatch monitoring via traditional and alternative means, and other groundbreaking research. However, the list of potential research suggested in bycatch implementation plans and suggested by the National Bycatch Working Group's report is extensive and would be costly to carry out. As the National Bycatch Strategy matures over the coming months and years, funding needs and priorities will be revisited. The attainment of adequate funding is essential to the success of the National Bycatch Strategy.

Some positive funding signs have already emerged regarding bycatch. The FY 2004 Department of Commerce budget passed by Congress contained \$3.8 million in new "reducing bycatch" funding. Of this total, \$1.3 million was used to carry out critical gear research and bycatch coordination efforts. Projects funded include:

1) Development and transfer of gear modifications and fishing practices to reduce turtle takes in pelagic longline fisheries, including evaluating 18/0 circle hooks and bait types (sardines and herring) in the directed tuna fishery,
2) Development of halibut excluders for the Gulf of Alaska groundfish fisheries and salmon excluders for pollock trawlers,
3) Use of underwater infrared video and imaging sonar to document and categorize groundfish behavior in front of and in the mouth of a bottom trawl, and
4) Development and testing of a system to allow observers to report protected species interactions from the high seas.

The remaining \$2.5 million of the FY 2004 new reducing bycatch funding was used to contract with fisheries observers to board fishing vessels and report on catch and bycatch. These funded observer coverage projects, which should contribute to the minimization of bycatch for red snapper, Gulf and south Atlantic grouper species, west coast groundfish, and New England groundfish, include the following:

1) South Atlantic/Gulf of Mexico shrimp otter trawl fisheries observer program,
2) California longline fishery observer program,
3) California coastal purse seine fishery observer program,
4) Video-based electronic monitoring of hook and line bycatch, and
5) Analysis of Atlantic and Gulf of Mexico shrimp trawl bycatch data.

The Definition of Bycatch

As mentioned previously, the 1998 NMFS report "Managing the Nation's Bycatch" (NMFS, 1998) defined bycatch as "discarded catch of any living marine resource plus retained incidental catch and unobserved mortality due to a direct encounter with fishing gear." This definition expanded the scope of the definition of bycatch found in the MSFCMA, which does not specify retained incidental catch or unobserved mortality in its definition. The expanded definition of bycatch was designed to allow scientists and managers the opportunity to examine the full spectrum of total fishing-related mortality within the context of a national policy, consistent with NMFS's mission to build sustainable fisheries. "Managing the Nation's Bycatch" was meant to be a strategic document to assist the agency in meeting its goals not only under the MSFCMA, but also under the MMPA, the ESA, other domestic statutes, and international agreements.

In the summer of 2004, as the National Bycatch Strategy was implemented, some Chairs of regional FMC's expressed concern about including retained incidental catch in the definition of bycatch, because in some fisheries, retained incidental catch is a secondary catch that nonetheless constitutes an important component of a fishery's overall landings. For example, in the Hawaii longline fishery, vessels that target swordfish or tunas operate in the expectation that they also will catch a wide range of other marketable pelagic species. According to the regional FMC Chairs, requiring the Councils to minimize this incidental catch in accordance with the MSFCMA's National standard 9 could have catastrophic economic effects on some fisheries.

In response to such concerns, the NMFS policy definition of bycatch, published in "Evaluating Bycatch" (NMFS, 2004) is "the discarded catch of any living marine resource due to a direct encounter with fishing gear." Although this definition does not include retained incidental catch, it will assist NMFS with addressing bycatch problems regardless of whether the bycatch is discards, retained incidental catch, or protected species interactions. "Evaluating Bycatch" states NMFS's position that requiring retention of all species caught does not necessarily eliminate the problem of bycatch, and that it is critical to account for all catch—including target catch, bycatch, and retained incidental catch—and institute catch restraints as necessary to alleviate problems caused by excessive catch.

Conclusion

Bycatch is an important issue facing NMFS today. The requirements in current law to reduce bycatch underscore the value of living marine resources to

the nation as well as the commitment to ensure that these resources are protected and sustained for future generations. The NMFS National Bycatch Strategy has to date served as an effective vehicle to elevate the profile of bycatch in the agency and inspire a renewed commitment to bycatch reduction and minimization agency-wide. The attainment of adequate funding and other support is essential to the success of the National Bycatch Strategy. Although positive signs have already materialized in the form of increased Congressional attention to and funding of bycatch reduction efforts, making progress on bycatch reduction will require continued support and attention to this important issue from all of NMFS's partners, including the fishing industry, state fishery managers, scientists, environmental organizations, and Federal lawmakers.

Literature Cited

Castro, K., T. Corey, J. DeAlteris, and C. Gagnon. 1996. Proceedings of the East Coast Bycatch Conference. Newport, R.I., April 7–8, 1995. Univ. R.I. Sea Grant Program, Narragansett, 159 p.

NMFS. 1998. Managing the nation's bycatch: priorities, programs and actions for the National Marine Fisheries Service. NOAA. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Silver Spring, Md., 192 p.

________ . 2004. Evaluating bycatch: a national approach to standardized bycatch monitoring programs. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Silver Spring, Md., 108 p.

University of Alaska Sea Grant Program. 1996. Solving bycatch: considerations for today and tomorrow. Proceedings of a symposium, Seattle, WA, September 25–27, 1995. Alaska Sea Grant Coll. Prog. Rep. 96-03, Univ. Alaska, Fairbanks, 322 p.

USDOC. 2003a. Notice of receipt of petition for rulemaking and request for comments. U.S. Dep. Commer., Fed. Regist. 67 FR 19154–19155.

________ . 2003b. Notice of decision on petition for rulemaking on bycatch. U.S. Dep. Commer., Fed. Regist. 68 FR 11501–11518.

Warren, B. (Editor). 1994. Win-win bycatch solutions: a handbook for collaboration. Nat. Fish. Conserv. Cent., Seattle, Wash., 113 p.

Atlantic Blue Marlin, *Makaira nigricans*, and White Marlin, *Tetrapterus albidus*, Bycatch of the Japanese Pelagic Longline Fishery, 1960–2000

JOSEPH E. SERAFY, GUILLERMO A. DIAZ, ERIC D. PRINCE, ERIC S. ORBESEN and CHRISTOPHER M. LEGAULT

Introduction

Four billfish species (Family Istiophoridae) range the Atlantic Ocean and adjacent waters of the Caribbean Sea and Gulf of Mexico: sailfish, *Istiophorus platypterus*; blue marlin, *Makaira nigricans*; white marlin, *Tetrapturus albidus*; and longbill spearfish, *Tetrapturus pfluegeri* (Robins and Ray, 1986). In addition to filling the role of apex predators in subtropical and tropical pelagic waters, the Atlantic marlins and sailfish also support recreational fisheries that have been valued in the billions of dollars (IGFA, 1996). Despite their ecological and economic importance, little is known about the basic biology and ecology of these species, especially their growth, reproduction, and movement within the vast, highly dynamic oceanic habitats that sustain them (Holland, 2003).

Most research on Atlantic billfishes has focused on issues of stock structure, population abundance, and fishing mortality as part of stock assessments that, since 1994, have been performed every 2–4 years under the auspices of the International Commission for the Conservation of Atlantic Tunas (ICCAT). Several lines of evidence suggest that Atlantic blue marlin and white marlin belong to single Atlantic-wide stocks (Ortiz et al., 2003; Graves and McDowell, 2003); in contrast, sailfish are managed as western and eastern Atlantic populations. Results of the most recent ICCAT stock assessments (ICCAT, 2002; Restrepo et al., 2003) indicated that: 1) the Atlantic blue marlin population is overfished, with its current biomass about 40% of the size required for maximum sustainable yields (MSY); and 2) the white marlin stock is even more depleted, with its current biomass only 12% of the level to support MSY.

For at least the last two decades, the principal source of mortality on adults of both Atlantic marlin species has been pelagic longline fishing (Uozumi, 2003). This method of fishing deploys a continuous mainline, of up to 60 mi in length, with regularly spaced branch lines which terminate with baited hooks (Bjordal and Lokkeborg, 1996; Sainsbury, 1996). For the most part, billfish are not targeted by longline fisheries; rather, they are caught incidentally as the bycatch of fleets that strive to supply the growing global demand for tunas (Scombridae) and swordfish, *Xiphias gladius* (Prince and Brown, 1991; Beerkircher et al., 2002). Therefore, understanding bycatch of longline fisheries is an important step in reducing uncertainties in stock assessments and projections, implementing appropriate management measures, and developing new techniques to reduce incidental marlin capture, injury, and mortality.

The main purpose of this paper was to identify and analyze temporal and spatial patterns in Atlantic marlin by-

Joseph E. Serafy (joe.serafy@noaa.gov), Guillermo A. Diaz, Eric D. Prince, and Eric S. Orbesen are with the Southeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149. Christopher M. Legault is with the Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA,166 Water Street, Woods Hole, MA 02543.

ABSTRACT—Since the late 1950's, a multi-national longline fishery has operated throughout the Atlantic Ocean to supply the growing global demand for tunas (Scombridae) and swordfish, Xiphias gladius. *Two species caught as bycatch include Atlantic blue marlin,* Makaira nigricans, *and white marlin,* Tetrapterus albidus, *referred to in this paper as "Atlantic marlin." Pelagic longlining has consistently been the principal source of adult mortality for both species, which are currently depleted and have been so for more than two decades. In this paper, we examined aspects of the Atlantic marlin bycatch of the Japanese pelagic longline fishery from 1960 to 2000. Temporal and spatial patterns in effort, target catch (species combined), marlin bycatch, marlin catch-per-unit-effort (nominal CPUE), and ratios of marlin bycatch to target catch (B: T ratios) were analyzed. An objective was to reveal changes, if any, in marlin bycatch associated with the fishery's target species "switch" (ca. 1980–87) from mostly surface-associated tunas to mostly the deeper-dwelling bigeye tuna,* Thunnus obesus. *The highest values of all variables examined occurred during the 1960's and then fell by the second half of that decade. Since 1970, mean levels of fishing effort, target fish catches, and blue marlin landings have increased significantly, while blue marlin CPUE and B:T ratios have remained relatively stable. Concurrently, white marlin landings, CPUE, and B: T ratios have all declined. While results suggest the fishery's target species change may have been a factor in lowering white marlin bycatch, the same cannot be said for blue marlin. Relative increases in blue marlin B: T ratios off the northeastern coast of South America and in the wider eastern Atlantic are cause for concern, as are continuing trends of CPUE decline for white marlin in this data set as well as others.*

catch as reflected in the Japanese pelagic longlining database, which is the longest-running, most spatially-extensive of its kind (Myers and Worm, 2003). Historical trends in catch-per-unit-effort (CPUE) derived from this data source have been central components of billfish stock assessments, especially for gauging past and present fishing levels and removals relative to MSY (Jones et al., 1998; ICCAT, 2001, 2002; Restrepo et al., 2003; Uozumi, 2003). Our focus here was on variation in marlin bycatch within a 41-yr period (1960–2000) in the subtropical and tropical Atlantic Ocean between lat. 30°N and 30°S—where the bulk of Atlantic marlin catches occurs (Uozumi, 2003).

Of particular interest were quantitative changes that were consistent (or not) with the assertions first posed by Uozumi and Nakano (1994) and then repeated in several papers thereafter (e.g. Yokawa and Uozumi, 2001; Uozumi, 2003), that the relatively low Atlantic blue marlin CPUE's obtained by this fishery since the 1980's were not indicative of low population levels, but rather were artifacts of changes in fishing practices.

Specifically, Yokawa and Uozumi (2001) and Uozumi (2003) suggested that the operational switch from targeting mainly surface-associated albacore, *Thunnus alalunga*, and yellowfin tuna, *Thunnus albacares*, to targeting mainly the deeper-dwelling bigeye tuna, *Thunnus obesus*, has meant: 1) the gear only covered the lower limits of the blue marlin's depth distribution, and 2) shifting of fishing effort to focus on eastern Atlantic waters has amounted to movement away from preferred blue marlin habitats. Their implication, therefore, is that a drop in blue marlin catchability was the basis for any observed decline in blue marlin CPUE, and thus it should not be used, without adjustment, as an index of blue marlin abundance. It is unclear why the same argument was not made to explain the much greater declines in white marlin CPUE.

In this paper, we computed annual effort, target species catch, and marlin bycatch levels as well as CPUE and bycatch ratios (i.e. number of marlin caught per 100 target fishes, B:T ratio) for each Atlantic marlin species. More emphasis was placed on patterns of marlin B:T ratios than on CPUE precisely because the equivalency of effort units (Hilborn and Walters, 1992) over the time series has been questioned. Our objectives were to examine: 1) temporal variation in effort, target catch, and marlin bycatch before, during, and after the fishery's operational switch, 2) spatial changes in fishing effort, marlin CPUE, and marlin B:T ratios, 3) the extent to which marlin B:T ratios have been driven by concurrent changes in target and marlin catches, and 4) the theoretical interrelationships among bycatch and target species catchability and bycatch and target species abundance and how these ultimately affect B:T ratio levels.

Materials and Methods

The data analyzed here were a subset of the pelagic Japanese longline (JLL) data series, provided on request by ICCAT. The JLL data series comprises historical (i.e. from 1956 forward) catch and effort information, aggregated on a monthly basis and at the geographic scale of 5° latitude by 5° longitude cell. Effort in the JLL is given as total number of longline hooks deployed and catch as numbers of boated and discarded tunas (several species), swordfish, and istiophorid billfishes. In this investigation, we focused on patterns of blue marlin and white marlin bycatch from 1960 to 2000 and within Atlantic waters between lat. 30°N and 30°S. The spatial focus was chosen because Japanese longline bycatch of marlins beyond these latitudes is relatively minor (Uozumi, 2003). Sailfish and longbill spearfish bycatch trends were not considered because, prior to the late 1990's, catches listed as sailfish actually included an unspecified proportion of longbill spearfish (Uozumi, 2003).

Plots were generated to examine annual variation as well as average decadal patterns in: 1) fishing effort (number of longline hooks deployed), 2) target fish catch (i.e. number of tunas and swordfish combined), 3) blue marlin and white marlin bycatch (in numbers), 4) nominal CPUE for each marlin species (e.g. number of marlin caught per 1,000 hooks), and 5) species-specific

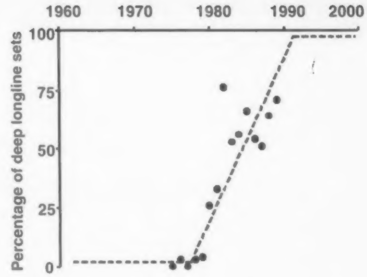


Figure 1.—Percentage of deep longline deployments made by the Japanese pelagic longline fishery in Atlantic waters. Based on data and depth definitions reported by Uozumi and Nakano (1994, Table 2) where a "deep longline" has a theoretical maximum hook depth ranging from 170 to 300 m. Dotted line in plot indicates general trend as described by Uozumi and Nakano (1994).

marlin B:T ratios (number of marlin per 100 target fishes). Marlin bycatch ratios were calculated as $100{*}B_{x,t}/T_t$, where B_x is the total number of marlin of species x captured in year t, and T_t is the total number of target fishes (i.e. tunas and swordfish combined) captured in that same year.

"Decadal" variation in fishing effort, target catch, marlin bycatch, and ratios thereof was evaluated by comparing mean levels before (1960's and 1970's), during (1980's) and after (1990–2000) the Japanese longline fishery's switch from mainly shallow- to deep-fishing configurations (Fig. 1) and its concurrent shift to concentrate on eastern Atlantic waters. Decades were chosen as the unit of time based on the relatively long life span of both marlin species (Wilson, 1984; Hill et al., 1989). Our decadal comparisons (note that 1990–2000 is 11 years, not ten) were made using analysis of variance (ANOVA) models, followed by t-tests, with time period as the independent variable, and fishing effort, target catch, marlin bycatch, marlin CPUE, and marlin B:T ratio as dependent variables.

Following Sokal and Rohlf (1981), problems of non-normality and heterogeneity of variance were minimized via data transformation prior to statistical analyses: fishing effort, target catch, and

marlin bycatch values were $\log_e$-transformed, and marlin CPUE and B:T ratio were arcsine-transformed. When comparing means, the Bonferroni method (Sokal and Rohlf, 1987) was used such that "experiment-wise" error rate was held at the P<0.1 level. Also examined at the decadal scale were spatial changes in the distribution and intensity of fishing effort, marlin CPUE, and marlin B:T ratios. This was achieved by computing, for each 5° by 5° cell, decadal averages (from annual totals) and generating maps using the geographical information system software ArcMap.[1]

The "evolution" of the marlin bycatch (a measure of the fishery's inefficiency) over the 41-year time period was examined by plotting what are termed here as marlin "bycatch time trajectories." Specifically, each year's position in an x-y plot was graphed, where the absolute number of target fishes constituted the x-coordinate and the absolute number of a given marlin captured constituted the y-coordinate. In other words, construction of our marlin bycatch time trajectories amounted to plotting the numerator of a given annual B:T ratio against its denominator. Likewise, the mean decadal position (i.e. with vertical and horizontal error bars) of the fishery in this bycatch-target "space" was also graphed. Finally, we also explored, mostly from a theoretical standpoint, how B:T ratio values vary with relative changes in the catchability and abundance of both target and bycatch species.

Results

Annual Variation

Shown in Figure 2A–E, from 1960 through 2000, are annual patterns of fishing effort, numbers of target fishes caught, marlin bycatch numbers, marlin CPUE values, and marlin B:T ratios. Fishing effort peaked in 1965 at 82 million hooks, generally declined through 1970 and then gradually increased toward peak levels over the next 25 years (Fig. 2A). Concurrently, the relative proportion of individual target species and their combined numbers changed considerably (Fig. 2B). Highest target species landings were in 1964, when about 3.1 million individual target fishes were harvested with albacore, yellowfin tuna, bigeye tuna, and swordfish constituting 61, 27, 10, and 0.95% of the total target catch, respectively. By 1976, target fish catches had declined to a historical low of about 177,000 individuals, with bigeye tuna alone constituting about half of the catch. From 1976 forward, numbers of target fishes generally increased such that 2000 landings were over 600,000 individuals, with bigeye tuna accounting for 82% of the catch.

Atlantic marlin bycatches (Fig. 2C) generally tracked target fish catches, with the highest numbers of each marlin spe-

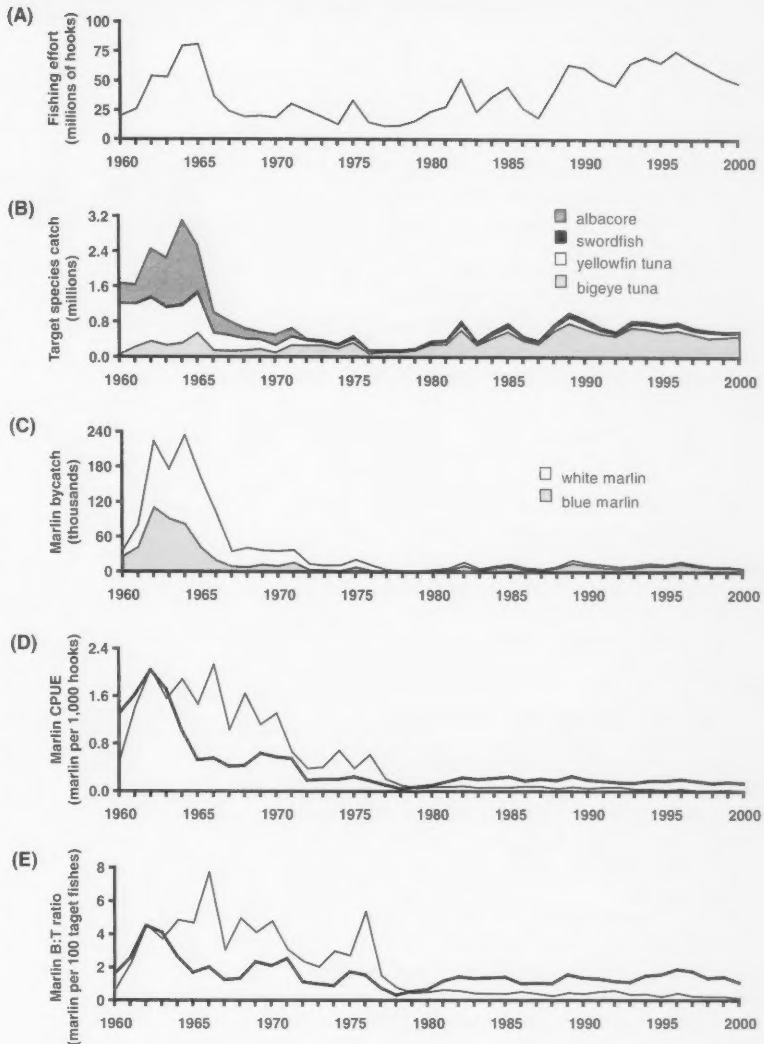


Figure 2.—Historical patterns in (A) fishing effort, (B) target species catch, (C) marlin bycatch, (D) marlin CPUE, and (E) marlin B:T ratios. Panels (B)–(C) are stacked area graphs. Bold and light lines on panels (D) and (E) pertain to blue marlin and white marlin, respectively.

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

cies caught per annum in the early to mid 1960's, then dropping to low levels by the late 1970's. Thereafter, blue marlin bycatch levels increased slightly and remained stable, whereas white marlin continued a slow, but steady decline through to the end of the time series. Annual variation in blue marlin and white marlin CPUE levels are shown in Figure 2D. For blue marlin, the highest annual CPUE occurred in 1962, after which CPUE declined over 45-fold to a historical low in 1978 of 0.044 blue marlin per 1,000 hooks. Four years later, blue marlin CPUE had increased about five-fold and then remained somewhat level through the end of the time-series. For white marlin, the highest CPUE values occurred up until 1970, but these were followed by a rapid, consistent decline through to the end of the time-series with the historical low occurring in the most recent year examined (i.e. 2000).

Year-to-year changes in the numbers of each marlin species caught per 100 target fishes (i.e. B:T ratios) are shown in Figure 2E. Blue marlin B:T ratios followed the same general pattern as corresponding CPUE values, except that the rate of decline from 1962 to 1978 was less severe (a three-fold reduction). From 1982 forward, blue marlin B:T ratios remained somewhat level, ranging from 1.0 to 1.9. Similarly, annual variation in white marlin B:T ratios resembled that of white marlin CPUE. Relatively high B:T ratio values (i.e. from 2.1 to 7.8) persisted from 1962 through 1976. This was followed by a rapid decline from 1976 to 1978, and then a more gradual decline from 0.82 in 1978 to 0.14 in 2000.

Temporal Comparisons

Figure 3 depicts results of the "decadal" analyses performed to examine for consistency with the assertion of Uozumi (2003). Mean annual fishing effort (i.e. average number of hooks deployed) initially dropped from over 40 million hooks in the 1960's to about 20 million hooks in the 1970's after which it increased steadily to almost 60 million hooks by the 1990–2000 time period (Fig. 3A). Concurrently, the catch of target fishes followed a similar pattern with a large drop from the 1960's to the 1970's followed by a statistically significant increase through the 1990–2000 time period (Fig. 3B). For both marlin species, mean bycatch levels dropped sharply from the 1960's to the 1970's, but then displayed very different patterns thereafter (Fig. 3C, D).

Whereas average bycatch of blue marlin increased two-fold from the 1970's to the 1990–2000 period, white marlin bycatch decreased by about two-thirds from the 1970's to the 1980's and remained at this level thereafter. Likewise, patterns of mean CPUE and B:T ratios also varied according to species. Highest mean levels for both species were during the 1960's, but in the case of blue marlin, no significant differences in mean CPUE or B:T ratio were detected from the 1970's forward (Fig. 3E, G).

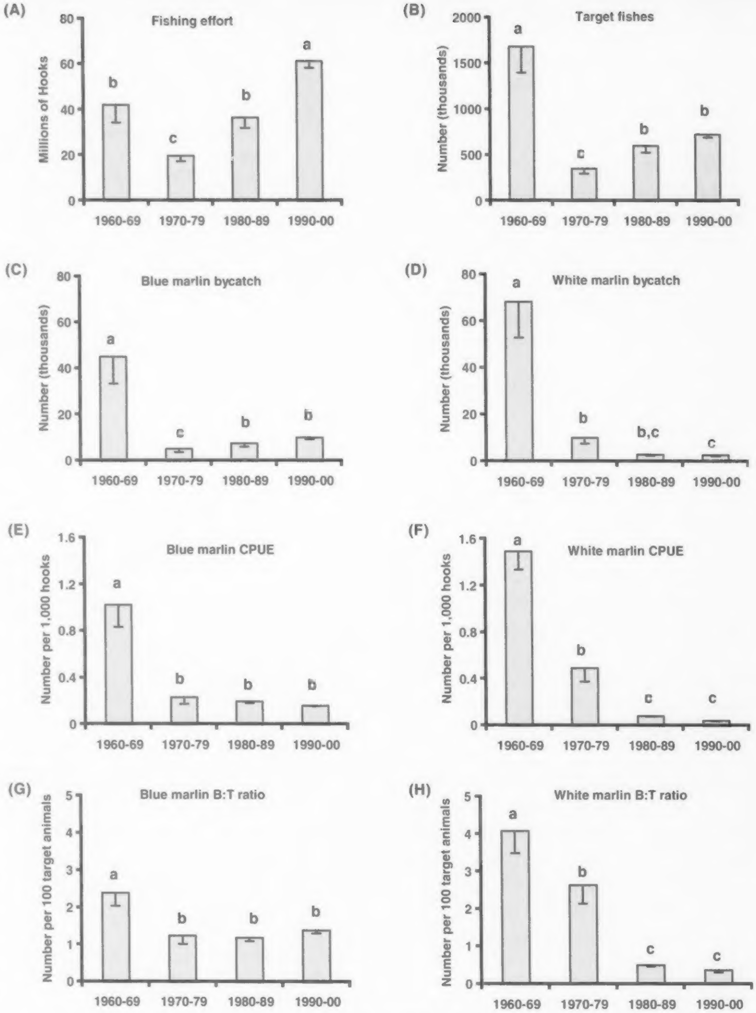


Figure 3.—Comparison of mean effort, target catch, marlin bycatch, and ratios thereof during the 1960's, 1970's, 1980's, and the 1990–2000 time periods. Statistical testing conducted after ln-transformation; ratios after arcsine-transformation. Bars sharing the same lowercase letter are not statistically different. Lines within bars indicate 1 standard error.

Conversely, mean CPUE and B:T ratio values of white marlin followed the same general pattern of their landings—an 80% or greater reduction occurring from the 1970's to the 1980's followed by a statistically equivalent mean in the 1990–2000 time period (Fig. 3F, H).

Spatial Patterns

The distribution and intensity of Japanese longlining fishing effort within Atlantic subtropical and tropical waters has expanded and contracted over the 41-year time series of data (Fig. 4). During the 1960's, fishing effort was distributed throughout the study area, with areas of high intensity throughout. This was followed by a decade of much-reduced fishing effort between lat. 30°N and S, especially in middle Atlantic waters, with the heaviest fishing occurring in the Gulf of Mexico and in two distinct areas off the northwestern and the southwestern African continent. The ensuing 1980's was a period of renewed spatial expansion in the study area with the highest fishing intensity again occurring in the eastern Atlantic Ocean, but more so in equatorial waters. Finally, the pattern of fishing effort during the 1990–2000 time period was much the same as that of the previous decade, with the intensity of fishing generally increasing in eastern Atlantic waters. It was also during this latest time period that the fishery vacated or greatly reduced effort in areas of the Gulf of Mexico, the Caribbean Sea, and east of the island chains of the Bahamas and Lesser Antilles.

The spatial distribution and magnitude of marlin CPUE values by decade are presented in Figure 5. Clearly, the 1960's was a period of high CPUE values for both species, especially in western Atlantic waters and for white marlin in particular. The pattern of greater blue marlin and white marlin CPUE values in the western Atlantic persisted in the 1970's, but with large reductions in magnitude, particularly in middle Atlantic waters. In general, the spatial pattern in blue marlin CPUE values was similar in the ensuing two time periods, but with an overall tendency for reduction. In contrast, for white marlin, there was a continual, ubiquitous decline throughout

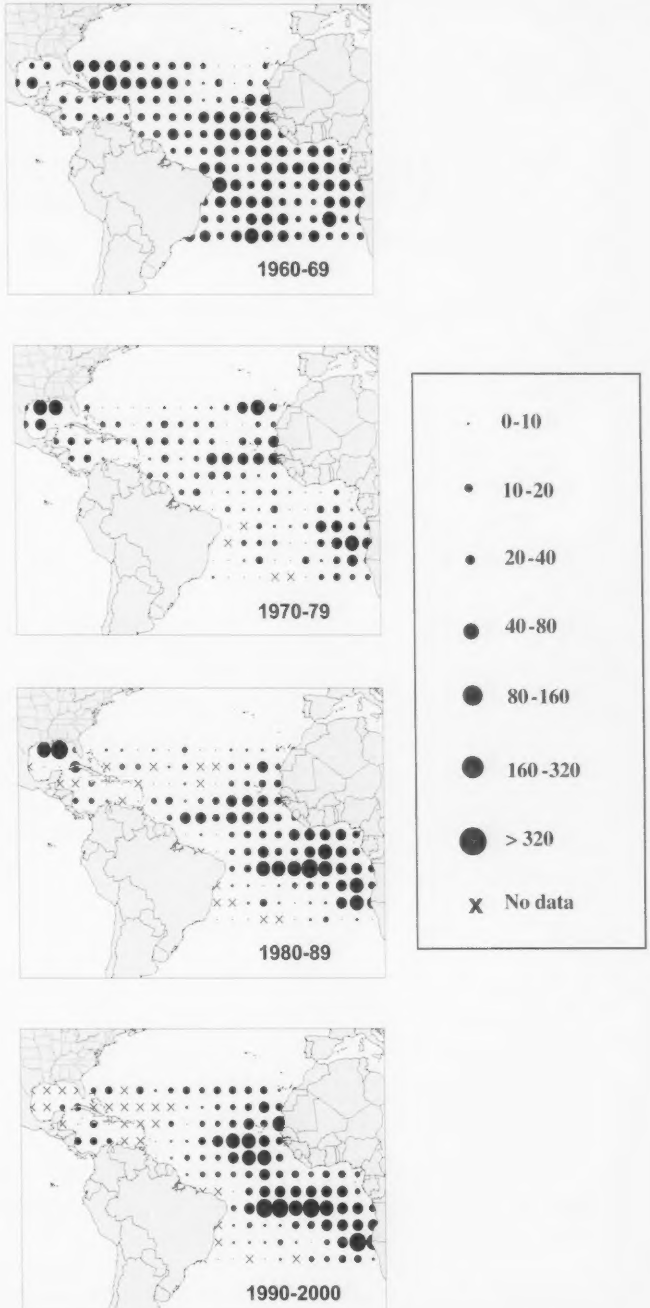


Figure 4.—Spatial distribution and intensity of Japanese longlining fishing effort in the Atlantic Ocean between lat. 30° N and S. Depicted is the average number of hooks deployed in each 5° × 5° cell per time period.

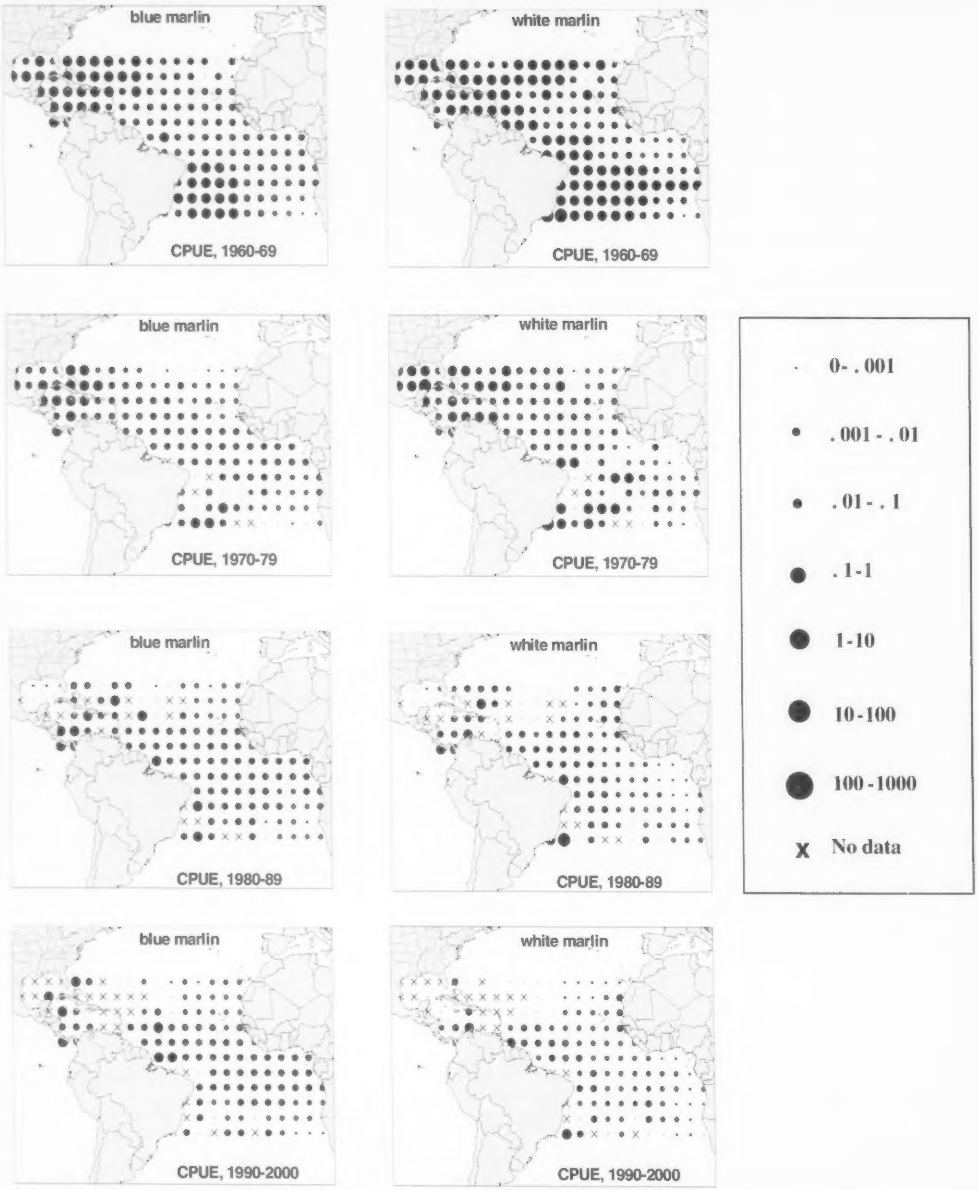


Figure 5.—Average marlin catch-per-unit-effort (number of marlin caught per 1,000 hooks) in the Atlantic Ocean between lat. 30°N and S.

the study area. Corresponding historical maps of marlin B:T ratios (Fig. 6) share many similarities with CPUE maps. The spatial pattern of marlin B:T ratios during the 1960's indicates generally high values throughout the domain for both species with a tendency for the highest values to occur in the western Atlantic. As with marlin CPUE, the magnitude of B:T ratio values are much reduced during the 1970's, especially in certain eastern and middle Atlantic areas. Again, the two marlin species respond differently after the 1970's with respect to B:T ratio. During the 1980's and the 1990–2000 time period, blue marlin B:T ratio maps indicate either minor change or increases in fished areas of

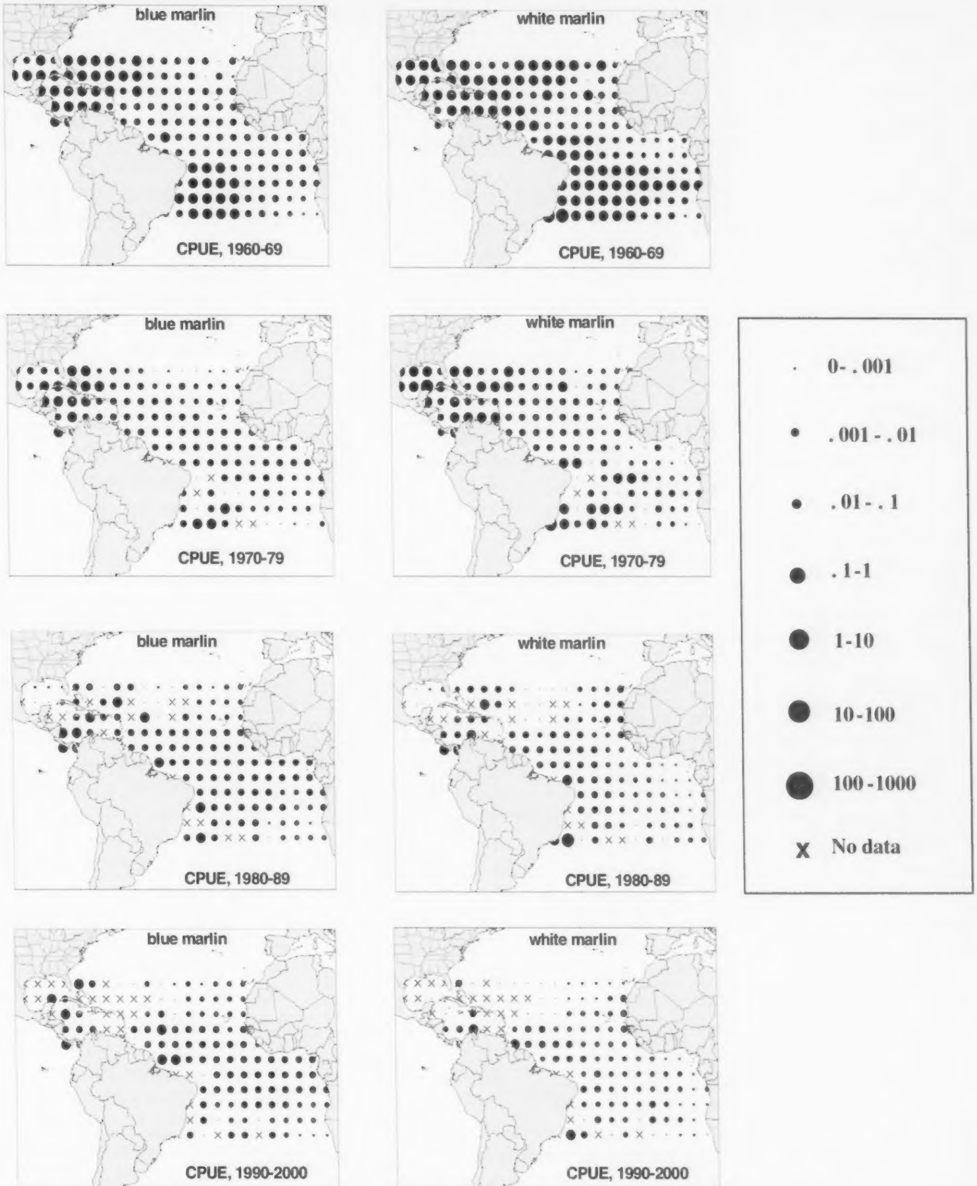


Figure 6.—Average marlin B:T ratio values (number of marlin caught per 100 target fishes) in the Atlantic Ocean between lat. 30°N and S.

the Caribbean Sea, off Brazil, and off the southern African coast. Concurrently, white marlin B:T ratio maps indicate severe reduction in values throughout the entire study area, especially by the 1990–2000 time period. These results imply that shifts in fishing grounds have had lesser effects on white marlin B:T ratios relative to other changes, such as those of gear configuration.

Bycatch Time Trajectories

A major limitation of using B:T ratios alone is that the magnitude of the numerator (B) and the denominator (T)

are hidden; we dealt with this with our bycatch time trajectory graphs whereby numbers of both marlin species were plotted against numbers of target fishes (Fig. 7). This data presentation allows the "tracking" (from one year to the next) of the fishery's efficiency (strictly, inefficiency) at catching marlins over the 41-year time period. The bycatch time trajectory of blue marlin and white marlin are broadly similar in that it is during the 1960's that the highest bycatch and target catch values (as well as the greatest inter-annual changes) occur for both species. Likewise, during the 1970's, for both marlin species, the fishery "moves" towards the origin with the lowest bycatch and target catch numbers occurring at the end of this decade. However, after the 1970's, the bycatch trajectories for blue marlin and white marlin diverge. Whereas blue marlin numbers increase as target catch numbers increase during the ensuing 21 years, white marlin numbers remain consistently low. Figures 7E and 7F emphasize this difference by showing the average coordinates (± 1 standard error) in marlin bycatch—target catch "space" during the 1970's, 1980's, and the 1990–2000 time periods.

Discussion

The Japanese longlining data set examined here has been invaluable in numerous single-species stock assessments (see ICCAT, 2002) for assessment results on bluefin tuna, yellowfin tuna, albacore tuna, bigeye tuna, white marlin, blue marlin, and sailfish) and, most recently, as a means of quantifying changes in pelagic predatory fish communities in the global ocean (Myers and Worm, 2003). As the primary index of the relative abundance of one or more target or bycatch species, catch-per-unit-effort, and historical changes therein, has received the most scrutiny in previous analyses. By comparison, little attention has been placed on ratios of bycatch to target species (B:T ratios) and how these have varied over time and space (though see Goodyear, 1999). Similarly, debate over what CPUE trajectories imply about marlin stocks (see Goodyear, 2003) and Uozumi (2003) for contrasting points of view) has deflected attention away from trends in absolute quantities of marlin bycatch, which, in the case of blue marlin, have increased significantly since the purported operational switch.

Evident from our analyses was that it was during the 1960's that the highest values of all variables examined occurred. Fishing effort, target catch, marlin bycatch, marlin CPUE's, and marlin B:T ratios all peaked in the early or mid 1960's and, overall, then fell

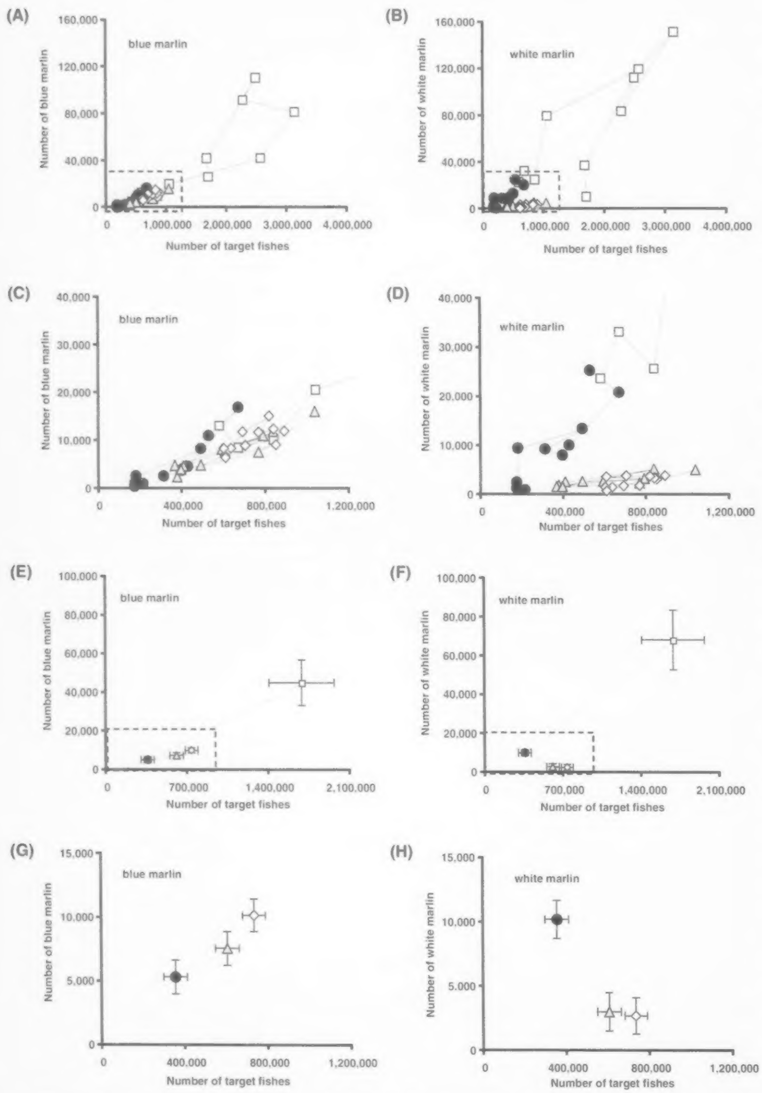


Figure 7.—Marlin bycatch time trajectories. Squares, dots, triangles, and diamonds, respectively, indicate years of the 1960's, 1970's, 1980's, 1990's, and 2000. Panels E–H show decadal mean values (± 1 S.E.). Note that plots in panels C and D are expanded views of areas defined by dotted lines in panels A and B. Likewise, plots in panels G and H are expanded views of areas defined by dotted lines in panels E and F.

during the second half of that decade. Since 1970, mean levels of fishing effort, target fish catches, and blue marlin bycatch have increased significantly while blue marlin CPUE and B:T ratios have remained relatively stable. Concurrently, white marlin landings, CPUE, and B:T ratios have all declined drastically. All the above occurred as fishing grounds were shifted to focus on eastern Atlantic waters and gear was deployed to allow for deeper fishing to better target bigeye tuna. Presumably, an underlying reason for increased targeting of bigeye tuna was economic. In the Tokyo sashimi market, albacore, yellowfin, and bigeye tuna had similar values during the 1960's, whereas by the early 1990's, bigeye tuna commanded over triple the prices of each of the other species (Fonteneau, 1998).

Implicit in calculation of B:T ratios over time is that any change in catchability for the target species is known. Catchability for an individual species can change due to fishing operations or advances in technology but are often relatively minor and assumed constant in many stock assessments. Of more concern for this case is that the relative proportion of species in the target catch can change over time, implying a change in overall catchability if the catchability of each species is different. Given the similar order of magnitude for catches of the different target species at their respective peaks, we do not think this is a problem for our analyses of the Atlantic marlin B:T ratios. However, we note that almost all of the change in target species composition occurred during the 1960's and have remained relatively constant since 1970, with bigeye tuna as the dominant target species.

Uozumi and Nakano (1994) and Uozumi (2003) have not contested that Atlantic blue marlin and white marlin stocks were larger during the 1960's than at any point since. However, they have attributed low blue marlin CPUE levels obtained since the mid 1980's to changes in fishing practices and fishing grounds rather than to low or declining population levels. Whereas our white marlin bycatch, CPUE, B:T ratio, and bycatch time trajectory results could be construed as being consistent with this scenario, the same cannot be said of blue marlin. We contend that if the fishery's effective effort had indeed shifted away from primary blue marlin habitat, this would be reflected in lower average B:T ratios for this species. For the most part, this has not transpired, and whatever the operational changes that have, or have not, occurred, it appears that this fishery is no less efficient at capturing blue marlin. Consequently, because on average JLL fishing effort has about doubled from the 1970's to the 1990–2000 time period, so too has the blue marlin bycatch of this fishery.

Two interrelated assumptions form the basis of the fishing operation change argument of Uozumi and Nakano (1994) and Uozumi (2003): 1) that blue marlin are restricted to the shallowest strata of the water column, and 2) that longline fishing gear configured to fish deeply, usually does so. Electronic tagging and experimental longline fishing studies indicate greater utilization by both Atlantic marlin species of shallow vs. deep waters (Yang and Gong, 1988; Block, 1990); however, multiple daily excursions to depths of >200 m by blue marlin are not uncommon. This frequent deep-diving behavior, especially if associated with foraging (Graves et al., 2002; Kerstetter, 2003), may be the reason for the relative stability of blue marlin CPUE values and B:T ratios from 1970 forward. While the fishery may never have been fishing "deep enough" to reduce blue marlin bycatch, it is possible that some reduction in white marlin bycatch has occurred, although the magnitude of this reduction is unclear. The work of Yang and Gong (1988), Block (1990), and Horodysky et al. (2003) support the notion that white marlin inhabit, and presumably feed within, shallower depth strata than blue marlin; this may be a consequence of white marlin possessing lesser quantities of brain-eye heater tissue as compared to blue marlin (Block, 1990). That said, we are unconvinced that fishing depth changes have been a major contributor to the post-1979 patterns of CPUE and B:T ratio decline for white marlin. This is because other independent data sources, which are not complicated by major fishing operation changes, also point to drastic declines in white marlin population levels (ICCAT, 1994, 1998, 2001, 2003a). Therefore, we suspect that any reduction in white marlin catchability resulting from the JLL fishing deeper in the water column has not had a substantial effect on white marlin stock abundance, especially given that fisheries of nations other than Japan have combined to inflict most of the fishing mortality on this species in recent years.

Direct testing of the second (implicit) assumption behind the Uozumi (2003) contention (i.e. that a longline gear rigged to fish deeply, actually does) can be achieved via the attachment of electronic time-depth recorders (TDR's) in close proximity to baited longline hooks. Conversion of a longline from shallow- to deep-fishing typically entails increasing the distance between floats and/or extending the length of branch lines. While these measures can increase the maximum depths at which hooks settle, oceanographic conditions, gear deployment and retrieval velocity, hooked fish, and numerous other factors tend to conspire to make actual hook depths shallower than predicted from gear geometry (i.e. from catenary curves). This is readily apparent in experimental longline studies using TDR's such as that of Boggs (1992) who found that his gear averaged between 54% and 68% of predicted depths. Similar studies by Yanno and Abe (1998), Berkeley and Edwards (1998), and Mizuno et al. (1999) tend to corroborate this finding. Furthermore, as pointed out by Goodyear et al. (2003), all gear, regardless of configuration, must spend some time in the shallowest depth strata. Therefore, the estimated depth of capture of fish hooked when baits are either sinking during gear deployment or rising during gear retrieval will tend to be over- rather than underestimated. To better resolve the behavior of pelagic fish and the behavior of longline gear, Goodyear et al. (2003) and ICCAT (2003b) recommended further studies that combine TDR's and hook timers (electronic devices that record strike time) as well as the use of electronic archival tags. The use of archival tags holds great promise for quantifying habitat use and behavior

of bycatch and target species as these devices can be programmed to record minute-by-minute measurements of the depths and temperatures experienced by their bearers along with estimates of geolocation for periods of months to years (Arnold and Dewar, 2001).

Analyses of B:T ratios (alone) shed no light on stock abundance or the population status of these species—nor can they. Unlike CPUE, the B:T ratio is a measure of a fishery's efficiency to harvest desirable species over undesirable ones. Among the potential benefits of using B:T ratios are that they are simple to compute, economically relevant and, therefore, readily grasped by fishers, managers, and the public. Also, the mapping of marlin B:T ratios has been shown to have utility for identifying potential time-area closure locations (Goodyear, 1999). In this study, relative increases in blue marlin B:T ratios off the northeastern coast of South America and in the entire eastern Atlantic are cause for concern as are continuing trends of CPUE decline (well after the target switch) for white marlin in this data set as well as others (ICCAT, 2001, 2003a).

Unfortunately, the magnitude of marlin B:T ratios observed in this study are not easily compared with those of other fisheries because (matched) bycatch and target species quantities are rarely reported on a species-specific basis and, when ratios are calculated, they are often computed using fish weights (Alverson et al., 1994; Hoey, 1995; Gaertner et al., 2002; Romanov, 2002). For the purpose of comparison, we computed mean marlin B:T ratios using data contained in the U.S. pelagic longline logbook database (Cramer, 1996). By our calculation, blue marlin and white marlin B:T ratios for this fishery for the period 1992–2000 (and in the same spatial domain) have been 1.8 and 1.3, respectively; recall that corresponding values were 1.4 and 0.4 for the Japanese fishery. No doubt the apparently large discrepancy between white marlin B:T ratio values obtained for the U.S. vs. the JLL fishery is due to a combination of fishing technique differences and higher abundances of this species in the western Atlantic waters compared to the region as a whole.

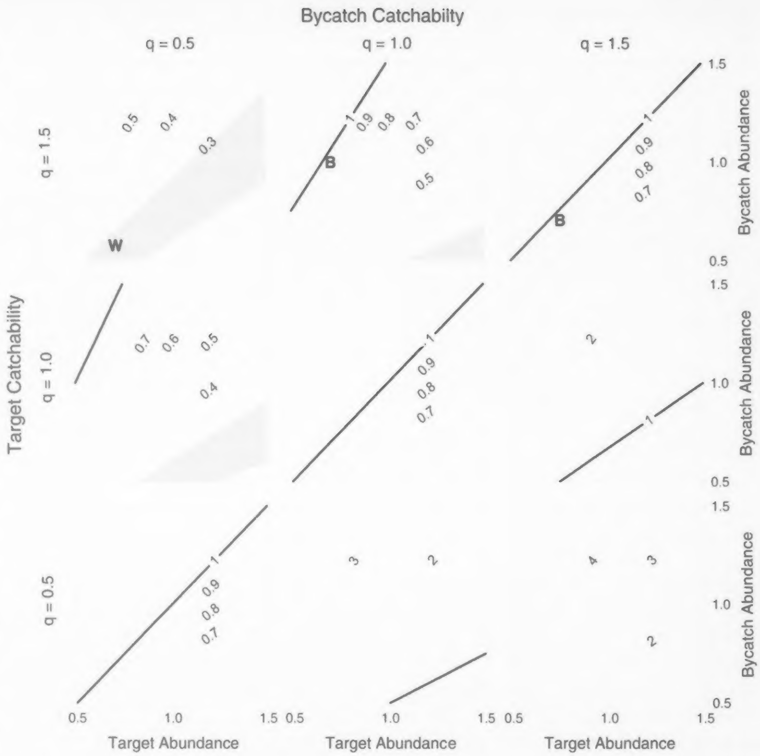


Figure 8.—B:T ratios for combinations of relative change in bycatch catchability (columns), target catchability (rows), target abundance (x-axis of plots), and bycatch abundance (y-axis of plots). Isopleths are shown in increments of 0.1 for values below 1.0 and in increments of 1.0 for values above 1.0. The thick line in each plot (if visible) denotes the no change in B:T ratio isopleth, roughly corresponding to the case of blue marlin. The shaded region in each plot (if visible) denotes the decline to 20–30% of original B:T ratio, roughly corresponding to the case of white marlin. The "W" and "B" in the top row of panels indicate likely position(s) of white marlin and blue marlin, respectively, during the 1990–2000 time period relative to the 1970's.

Whatever the cause, there is clearly room for testing new methods and approaches that further reduce the efficiency of all longline operations to capture unwanted species, including marlins. These include experimenting with different hook types (Prince et al., 2002) and baits (Broadhurst and Hazin, 2001), time-area closures (Goodyear, 1999), and perhaps novel bycatch avoidance devices, such as acoustic pingers (Barlow and Cameron, 2003).

An important feature of the B:T ratio is that it integrates changes in the quantity and location of effort. This can be seen by writing out the catch equation for both the bycatch and target species as $C(x) = q(x)*f*N(x)$ where C=catch, q=catchability, f=effort, N=abundance, and x denotes either bycatch or target species. The B:T ratio is thus $q(B)*N(B)/[q(T)*N(T)]$, and effort has been removed from the equation. Removal of effort as a variable is highly desirable in any case where the equivalency of effort units at the beginning vs. the end of a historical time series has been called into question (and when appropriate data for effort standardization are unavailable).

Figure 8 illustrates how changes in B:T ratio can be explained by combinations of the relative catchabilities and abun-

dances of the bycatch and target species. Whereas changes in one variable can be offset by equivalent relevant changes in another variable, in our case, the situation is somewhat simplified because we are not entirely ignorant about q(T) and N(T) over the 41-year time period. For example, the abundance of the main target species (bigeye tuna) is known to have decreased (ICCAT, 2002), and it is reasonable to assume that target species catchability has increased (i.e. especially given that, over the time period in question, vessel sizes and ranges have tended to increase, sophisticated marine electronics have been increasingly used, and new fishing gear materials, hydraulic systems, and numerous other developments have been adopted).

Given the above, what possible combination of abundance and catchability changes could have led to the marlin B:T ratio patterns observed in this study? If we assume that a 25% target abundance decrease coincided with a 50% target catchability increase from the 1970's to the 1990–2000 time period, then the left side of the panels in the top row of Figure 8 are relevant. In the case of the relatively stable blue marlin B:T ratios, either both bycatch abundance and catchability remained about the same, or a decrease in blue marlin abundance was offset by an equivalent increase in its catchability (two positions labeled "B" in Figure 8).

If blue marlin catchability reduction is hypothesized, however, it must have been offset by a decrease in target abundance that exceeded the combined influence of blue marlin abundance decrease and target catchability increase. Otherwise, the blue marlin B:T ratio would not have remained relatively constant. In contrast, the white marlin pattern of B:T ratio decline over the same time period suggests that this species' abundance and its catchability decreased (area labeled "W" in Figure 8). In fact, given the knowledge about changes in target abundance and catchability, an assumption of no change in bycatch catchability would require an extreme depletion of white marlin (>70%) to achieve the observed B:T ratio. This demonstrates one utility of B:T ratios—hypotheses regarding changes in bycatch catchability can be directly examined relative to observed or assumed changes in target catchability and abundance.

In conclusion, several distinct temporal, spatial, and species-specific patterns are apparent in the Atlantic marlin bycatch of the Japanese pelagic longline fishery from 1960 to 2000. The fishery has contracted and expanded geographically, generally reflecting a shift eastward, and varied considerably in terms of fishing intensity. The most obvious pattern shared by the marlins is that both stocks suffered their greatest declines well before bigeye tuna became the primary target species of this fishery.

Differences between species, that possibly reflect operational fishing changes, become apparent when absolute bycatch quantities, CPUE values, and B:T ratio values are examined from 1970 forward. We found no patterns consistent with the contention of Uozumi (2003) that targeting bigeye tuna has resulted in reduced blue marlin bycatch or that suggests that some catchability adjustment is warranted to gain a better historical perspective of long term population changes for this species. Whereas the possibility exists that white marlin catchability may have decreased, any benefits to its stock appear to have been eclipsed by the general increase in fishing effort on a population that, even in the most recent decade, shows evidence of consistent decline.

Clearly, further work is required to establish whether the bycatch patterns evident in the Japanese pelagic longline fleet are consistent with those derived from other pelagic fishing fleets operating in the Atlantic Ocean. Especially where past or future fishing practice or gear changes are of interest, the consideration of spatial and temporal patterns in species-specific B:T ratios may be a useful, complementary approach.

Acknowledgments

Partial support for this work was provided by the Center for Sustainable Fisheries, University of Miami, Florida. This paper benefited from the constructive criticisms of Steve Murawski and C. Phillip Goodyear. This paper is NOAA, National Marine Fisheries Service, Sustainable Fisheries Division contribution SFD-2004-001.

Literature Cited

Alverson, D. L., M. H. Freeburg, J. G. Pope, and S. A. Murawski. 1994. A global assessment of fisheries bycatch and discards. Food Agric. Organ., U.N., FAO Fish. Tech. Pap. 339, 233 p.

Arnold, G., and H. Dewar. 2001. Electronic tags in marine fisheries research. *In* J. R. Sibert, and J. L. Nielson (Editors), Electronic tagging and tracking in marine fisheries, p. 7–64. Kluwer Acad. Publ., Boston.

Barlow, J., and G. A. Cameron. 2003. Field experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gill net fishery. Mar. Mamm. Sci. 19: 265–283.

Beerkircher, L. B., C. J. Brown, and D. W. Lee. 2002. SEFSC pelagic observer program data summary for 1992-2000. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-486, 26 p.

Berkeley, S., and R. Edwards. 1998. Factors affecting billfish capture and survival in longline fisheries: potential application for reducing bycatch mortality. Int. Comm. Conserv. Atl. Tunas, Madrid, Coll. Vol. Sci. Pap. 48:255–262.

Bjordal, A., and S. Lokkeborg. 1996. Longlining. Fishing News Books, Blackwell Sci., Inc., Cambr., Mass., 156 p.

Block, B. A. 1990. Physiology and ecology of brain and eye heaters in billfishes. *In* R. H. Stroud (Editor), Planning the future of billfishes. Research and management in the 90's and beyond, p. 123–136. Proc. Second Int. Billfish Symp., Kailua-Kona, Hawaii, Aug. 1–5, 1988. Part 2: Contrib. pap. Mar. Rec. Fish. 13.

Boggs, C. H. 1992. Depth, capture time and hooked longevity of longline-caught pelagic fish: timing bites of fish with chips. Fish. Bull. 90:642–658.

Broadhurst, M. K., and F. H. V. Hazin. 2001. Influences of bait on catches of swordfish (*Xiphias gladius*) and other species in an artisanal sub-surface longline fishery off northeastern Brazil. Fish. Res. 53:169–179.

Cramer, J. 1996. Recent trends in the catch of undersized swordfish by the U.S. pelagic longline fishery. Mar. Fish. Rev. 58:24–32.

Fonteneau, A. 1998. A comparison of bigeye stocks and fisheries in the Atlantic, Indian and Pacific Oceans. *In* R. B Deriso, W. H. Bayliff, and N. J. Webb (Editors), Proceedings of the First World Meeting on Bigeye Tuna, p. 190–211. Inter-Am. Trop. Tuna Comm., Spec. Report 9.

Gaertner, D., F. Menard, C. Develter, J. Ariz, and A. Delgado de Molina. 2002. Bycatch of billfishes by the European tuna purse seine fishery in the Atlantic Ocean. Fish. Bull. 100:683–689.

Goodyear, C. P. 1999. An analysis of the possible utility of time-area closures to minimize billfish bycatch by U.S. pelagic longlines. Fish. Bull. 97:243–255.

__________. 2003. Mean hook depth—an unsuitable metric for computing effective effort for standardizing billfish longline CPUE. Int. Comm. Conserv. Atl. Tunas, Madrid. Collect. Vol. Sci. Pap. 55(2):669–687.

__________. D. Die, D.W. Kerstetter, D. B. Olsen, E. Prince, and G. P. Scott. 2003. Habitat standardization of CPUE indices: research needs. Int. Comm. Conserv. Atl. Tunas, Madrid. Collect. Vol. Sci. Pap. 55:613–623.

Graves, J. E., D. W. Kerstetter, B. E. Luckhurst, and E. D. Prince. 2002. Habitat preferences of istiophorid billfishes in the western north Atlantic: applicability of archival tag data to habitat-based stock assessment methodologies. Int. Comm. Conserv. Atl. Tunas SCRS/0/071, 10 p.

__________, and J. R. McDowell. 2003. Stock structure of the world's istiophorid billfishes: a genetic perspective. Mar. Fresh. Res. 54:287–298.

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, N.Y., 570 p.

Hill, K. T., G. M. Cailliett, and R. L. Radtke. 1989. A comparative analysis of growth zones in four calcified structures of Pacific blue marlin, *Makaira nigricans*. Fish. Bull. 87:829–843.

Hoey, J. J. 1995. Bycatch in western Atlantic pelagic longline fisheries. *In* Solving bycatch: considerations for today and tomorrow. Alaska Sea Grant Coll. Program Rep. 96-03, 322 p.

Holland, K. N. 2003. A perspective on billfish biological research and recommendations for the future. Mar. Fresh. Res. 54:343–347.

Horodysky, A. Z., D. W. Kerstetter, and J. E. Graves. 2003. Habitat preferences and diving behavior of white marlin (*Tetrapturus albidus*) released from the recreational rod-and-reel and commercial pelagic longline fisheries in the western North Atlantic Ocean: implications for habitat-based stock assessment models. Int. Comm. Conserv. Atl. Tunas SCRS/2003/033, 13 p.

ICCAT. 1994. Report of the second ICCAT Billfish Workshop. Int. Comm. Conserv. Atl. Tunas, Madrid. Collect. Vol. Sci. Pap., XLI, 587 p.

________. 1998. Report of the third ICCAT Billfish Workshop. Int. Comm. Conserv. Atl. Tunas, Madrid. Collect. Vol. Sci. Pap., XLVII, 352 p.

________. 2001. Proceedings of the Fourth Billfish Workshop, Miami, Florida USA. Stock Assessment Analyses. Int. Comm. Conserv. Atl. Tunas, Madrid. Collect. Vol. Sci. Pap. 53:10–110.

________. 2002. Report for biennial period, 2000-2001. Int. Comm. Conserv. Atl. Tunas, Madrid Spain. 2:Pt. II (2001), 204 p.

________. 2003a. Report of the 2002 ICCAT white marlin stock assessment meeting (Madrid, May 14-17, 2002). Int. Comm. Conserv. Atl. Tunas, Madrid. Collect. Vol. Sci. Pap. 55(2):350–452.

________. 2003b. Report of the 2003 Meeting of the ICCAT Working Group on Assessment Methods (Shimizu, Japan, 7–11 April, 2003). Int. Comm. Conserv. Atl. Tunas, Madrid. Collect. Vol. Sci. Pap., SCRS 2003/013.

IGFA. 1996. World record game fishes. Int. Game Fish Assoc., Pompano Beach, Fla., 352 p.

Jones, C. D., E. D. Prince, G. P. Scott, and M. I. Farber. 1998. Models of blue marlin and white marlin in the Atlantic Ocean: a case history. *In* F. Funk, T. J. Quinn II, J. Heifetz, J. N. Ianelli, J. E. Powers, J. F. Schweigert, P. J. Sullivan, and C.-I. Zhang (Editors), Fishery stock assessment models. Lowell Wakefield Fish. Symp., p. 99–119. Univ. Alaska Sea Grant Coll. Program Rep. 98-01.

Kerstetter, D. W., B. E. Luckhurst, E. D. Prince, and J. E. Graves. 2003. Use of pop-up satellite archival tags to demonstrate survival of blue marlin (*Makaira nigricans*) released from pelagic longline gear. Fish. Bull. 101:939–948.

Mizuno, K., M. Okazaki, H. Nakano, and H. Okamura. 1999. Estimating the underwater shape of tuna longlines with micro-bathythermographs. Inter-Am. Trop. Tuna Comm. Spec. Rep. I-ATTC, 10, 35 p.

Myers, R. A., and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423:280–283.

Ortiz, M, E. D. Prince, J. E. Serafy, D. B. Holts, K. B. Davy, J. G. Pepperell, M. B. Lowry, and J. C. Holdsworth. 2003. A global overview of the major constituent-based billfish tagging programs and their results since 1954. Mar. Fresh. Res. 54:489–507.

Prince, E. D., and B. E. Brown. 1991. Coordination of the ICCAT enhanced research program for billfish. *In* Proceedings of the international symposium and workshop on creel and angler surveys in fisheries management, p. 13–18. Houston, Tex. Am. Fish Soc. Symp. 12.

__________, M. Ortiz, and A. Venizelos. 2002. A comparison of circle hook and "j" hook performance in recreational catch-and-release fisheries for billfish. Am. Fish. Soc. Symp. 30:66–79.

Restrepo, V., E. D. Prince, G. P. Scott, and Y. Uozumi. 2003. ICCAT stock assessments of Atlantic billfish. Mar. Fresh. Res. 54:361–367.

Robins, C. R., and G. C. Ray. 1986. A field guide to Atlantic coast fishes of North America. Peterson Field Guide Series. Houghton Mifflin, Boston, 354 p.

Romanov, E. V. 2002. Bycatch in the tuna purse-seine fisheries of the western Indian Ocean. Fish. Bull. 100:90–105.

Sainsbury, J. C. 1996. Commercial fishing methods: an introduction to vessels and gears. Fishing News Books, Blackwell Sci., Inc., Camb., Mass., 359 p.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry. The principles and practice of statistics in biological research. W. H. Freeman and Co., N.Y., 859 p.

__________ and __________. 1987. Introduction to biostatistics. W. H. Freeman and Co., N.Y., 567 p.

Uozumi, Y. 2003. Historical perspective of global billfish stock assessment. Mar. Fresh. Res. 54:555–565.

Uozumi, Y., and H. Nakano. 1994. A historical review of Japanese longline fishery and billfish catches in the Atlantic Ocean. Int. Comm. Conserv. Atl. Tunas, Madrid. Collect. Vol. Sci. Pap. 17:471–486.

Wilson, C. A. 1984. Age and growth aspects of the life history of billfish. Ph.D. dissert., Dep. Biol., Univ. S. C., Columbia, 180 p.

Yang, W. S., and Y. Gong. 1988. The vertical distribution of tunas and billfishes and fishing efficiency between Korean regular and deep longlines in the Atlantic Ocean. Bull. Natl. Fish. Res. Dev. Agency [Pusan, Korea] 42:39–42.

Yanno, K., and O. Abe. 1998. Depth measurements of tuna longline by using time-depth recorder. Nippon Suisan Gakkaishi 64:178–188.

Yokawa, K. Y. and Y. Uozumi. 2001. Analysis of operation pattern of Japanese longliners in the tropical Atlantic and their blue marlin catch. Int. Comm. Conserv. Atl. Tunas, Madrid. Collect. Vol. Sci. Pap. ICCAT 53:318–336.

Estimates of Marine Mammal, Sea Turtle, and Seabird Mortality in the California Drift Gillnet Fishery for Swordfish and Thresher Shark, 1996–2002

JAMES V. CARRETTA, TIM PRICE, DON PETERSEN and ROBERT READ

Introduction

The California drift gillnet fishery for broadbill swordfish, *Xiphias gladius*, and common thresher shark, *Alopias vulpinus*, developed in the late 1970's when incidental catches of pelagic sharks in small-mesh coastal drift gillnets targeting barracuda, *Sphyraena argentea*, and white seabass, *Atractoscion nobilis*, motivated fishermen to experiment with large-mesh nets targeting thresher shark.[1] In 1979, 40 vessels participated in the fishery, and by the 1981–82 fishing season, over 6,000 sets were made by about 200 active permit holders (Herrick and Hanan, 1988; Hanan et al., 1993; Holts et al., 1998). Fishing effort peaked at over 10,000 sets in the 1982–83 and 1986–87 fishing seasons, after which effort declined, largely due to a combination of a limited entry system, net length restrictions, and a series of time/area closures (Hanan et al., 1993; Holts et al., 1998). NOAA's National Marine Fisheries Service (NMFS) began placing observers on drift gillnet vessels in 1990 to monitor marine mammal bycatch. Fishing effort at that time was about 4000–5000 sets. Effort had declined to about 1,700 sets by 60 vessels by 2002.

In the early to mid 1990's, the fishery was responsible for taking a number of marine mammal species at levels where estimated mortality exceeded potential biological removal (PBR) limits set under the Marine Mammal Protection Act (MMPA) (Barlow et al., 1997; Julian and Beeson, 1998). At that time, the fishery was considered to be a MMPA Category I fishery, where incidental mortality and serious injury of marine mammals is frequent and annual mortality and serious injury for a given stock or stocks exceeds 50% of PBR. A Take Reduction Team (TRT) was convened in 1996 with the goal of reducing marine mammal interactions with the fishery. The TRT recommended the experimental use of acoustic warning devices or "pingers," to test their effectiveness in reducing marine mammal bycatch. Experimental results demonstrated that entanglement rates of short-beaked common dolphins, *Delphinus delphis*, and California sea lions, *Zalophus californianus*, were significantly reduced in pingered nets (Barlow and Cameron, 2003). The effectiveness of acoustic pingers in this fishery led to their mandatory use in late 1997 (U.S. Dep. Commer., 1997).

Typical gear used in this fishery is an 1,800 m (1,000 fm) gillnet with a stretched mesh size ranging from 46 to 56 cm (18 to 22 in), with a required 36 cm (14 in) minimum. The net is attached to one end of the vessel, set at dusk, and allowed to drift during the night for 12 to 14 h. In the 1997–98 fishing season,

James V. Carretta (e-mail: Jim.Carretta@noaa.gov) is with the Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 8604 La Jolla Shores Drive, La Jolla, CA 92037. Tim Price and Don Petersen are with the Southwest Regional Office, National Marine Fisheries Service, NOAA, 501 West Ocean Boulevard, Long Beach, CA 90802. Robert Read is with the California Department of Fish and Game, 4949 Viewridge Ave., San Diego, CA 92123.

[1] Fishery Management Plan and Environmental Impact Statement for U.S. West Coast Fisheries for Highly Migratory Species. Pacific Fishery Management Council (PFMC), Aug. 2003.

ABSTRACT—Estimates of incidental marine mammal, sea turtle, and seabird mortality in the California drift gillnet fishery for broadbill swordfish, Xiphias gladius, *and common thresher shark,* Alopias vulpinus, *are summarized for the 7-year period, 1996 to 2002. Fishery observer coverage was 19% over the period (3,369 days observed/17,649 days fished). An experiment to test the effectiveness of acoustic pingers on reducing marine mammal entanglements in this fishery began in 1996 and resulted in statistically significant reductions in marine mammal bycatch. The most commonly entangled marine mammal species were the short-beaked common dolphin,* Delphinus delphis; *California sea lion,* Zalophus californianus; *and northern right whale dolphin,* Lissodelphis borealis. *Estimated mortality by species (CV and observed mortality in parentheses) from 1996 to 2002 is 861 (0.11, 133) short-beaked common dolphins; 553 (0.16, 103) California sea lions; 151 (0.25, 31) northern right whale dolphins; 150 (0.21, 27) northern elephant seals,* Mirounga angustirostris; *54 (0.41, 10) long-beaked common dolphins,* Delphinus capensis; *44 (0.53, 6) Dall's porpoise,* Phocoenoides dalli; *19 (0.60, 5) Risso's dolphins,* Grampus griseus; *11 (0.71, 2) gray whales,* Eschrichtius robustus; *7 (0.83, 2) sperm whales,* Physeter macrocephalus; *7 (0.96, 1) short-finned pilot whales,* Globicephala macrorhychus; *12 (1.06, 1) minke whales,* Balaenoptera acutorostrata; *5 (1.05, 1) fin whales,* Balaenoptera physalus; *11 (0.68, 2) unidentified pinnipeds; 33 (0.52, 4) leatherback turtles,* Dermochelys coriacea; *18 (0.57, 3) loggerhead turtles,* Caretta caretta; *13 (0.73, 3) northern fulmars,* Fulmarus glacialis; *and 6 (0.86, 2) unidentified birds.*

a net extender length of 11 m (36 ft, the minimum depth at which the top of the net may be fished) became mandatory. Vessel trips usually range from 5 to 18 days, depending on the area to be fished, weather, and fish availability. Effort in this fishery is highly seasonal, with > 70% of sets occurring between October and December. Season-area closures for this fishery require that effort must be further than 200 nautical miles (n.mi.) from shore from 1 February to 30 April; inclusive, and that effort must be further than 75 n.mi. from shore from 1 May to 14 August. Since August 2001, a season/area closure to protect leatherback turtles prohibits drift gillnet fishing from 15 August through 15 November in the area bounded by straight lines from Point Sur, Calif., (lat. 36°17′N) to lat. 34°27′N, long. 123°35′W, west to long. 129°W, north to lat. 45°N, then east to the Oregon coast (Fig. 1). Due to current season/area closures, fishing effort is concentrated in southern California waters (Fig. 2). An additional season-area closure south of Point Conception, Calif., and east of long. 120°W is effective during the months of June, July, and August during El Niño years to protect loggerhead turtles, *Caretta caretta*.

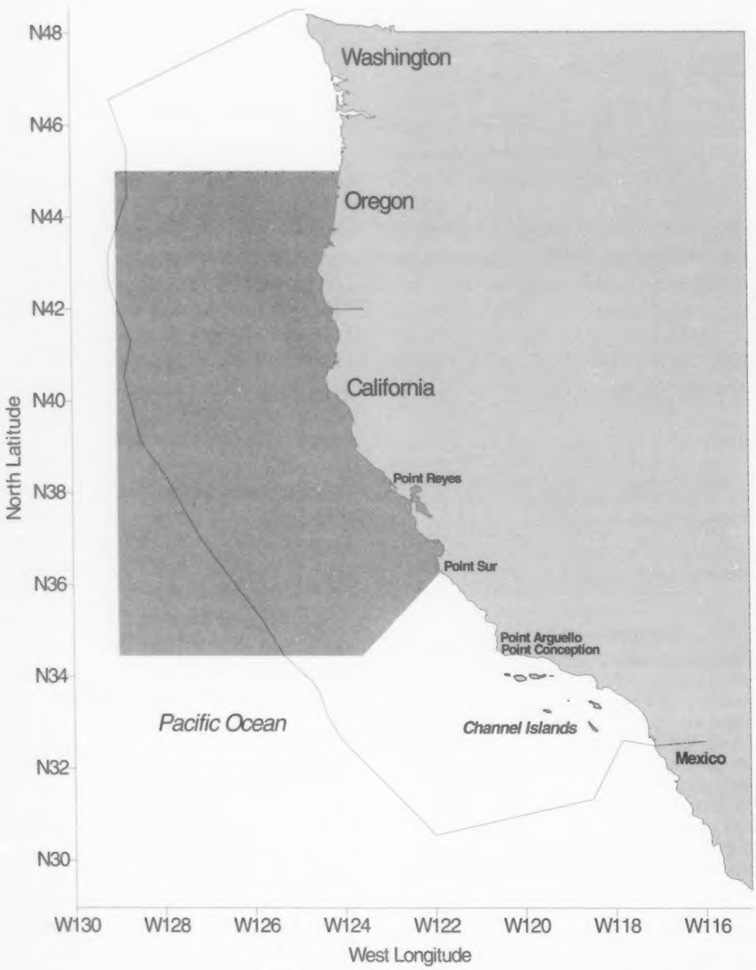


Figure 1.—Area fished by the California swordfish and thresher shark drift gillnet fishery. The solid line represents the U.S. Exclusive Economic Zone (EEZ). Dark gray region has been closed to fishing from 15 Aug. to 15 Nov. each year since 2001 to protect leatherback turtles.

Marine mammal, seabird, and sea turtle mortality in this fishery has been described for the period 1990–95 by Julian and Beeson (1998). Those authors reported estimates of 400–650 cetaceans and 100–200 pinnipeds killed annually, based on annual observer coverage that ranged from 4% to 18%. This paper summarizes the number of marine mammals, seabirds, and sea turtles observed killed annually in the California drift gillnet fishery for swordfish and thresher shark from 1996 to 2002, annual estimates of mortality, and total estimated mortality for the whole period.

Materials and Methods

Data Collection

Data on incidental entanglement and mortality of protected species is collected by observers that are placed on board drift gillnet fishing vessels. An attempt is made to sample at least every fifth vessel trip, with an overall goal of 20% observer coverage for the fishery. Not all vessels are observed, because smaller vessels have no berthing spaces to accommodate observers. During the 2002 fishing season, at least 13 vessels were unobserved, which were responsible for a minimum of 550 days of fishing effort (NMFS Southwest Regional Office, unpubl. data). Observers record information for each set, including location, presence, and functionality of pingers, and bycatch of protected species. During the 1996–97 pinger experiment, observers carried acoustic pingers with them, and, therefore, all pingered sets were observed during this period. For each marine mammal incidentally killed, observers record the species and gender of the animal. Additional biological data and samples (e.g. total body length, gonads, teeth, skin sample) are collected whenever possible. When practical, the entire carcass of the marine mammal is retained for life history studies. Species identifications made in the field are validated, if necessary, and corrected

using molecular genetic methods when the species identification is in doubt (Chivers et al., 1997; Henshaw et al., 1997). A summary of the number of species identifications corrected using genetic methods is presented in the Results section. A description of the data collected and life history information available from incidental kills in this fishery has been summarized in Chivers et al. (1997) and Henshaw et al. (1997). Occasionally, entangled animals were released with injuries that made future survival doubtful. These cases of "serious injuries" were defined by reviewing observer notes and comparing the extent of the injuries with the serious injury guidelines used by NMFS (Angliss and DeMaster, 1998). A serious injury is defined as "any injury that will likely to lead to mortality".[2] Serious injuries may include, but are not limited to, the following: animals released with trailing gear that would impair the animal's mobility or ability to feed, ingested hooks, visible blood flow, loss or damage to an appendage, listless appearance or inability to defend itself, inability to swim or dive upon release from fishing gear, signs of equilibrium imbalance, perforation of any part of the body by fishing gear, and animals that swim abnormally after release. Serious injuries were treated as observed mortalities and are included as such when estimating overall mortality.

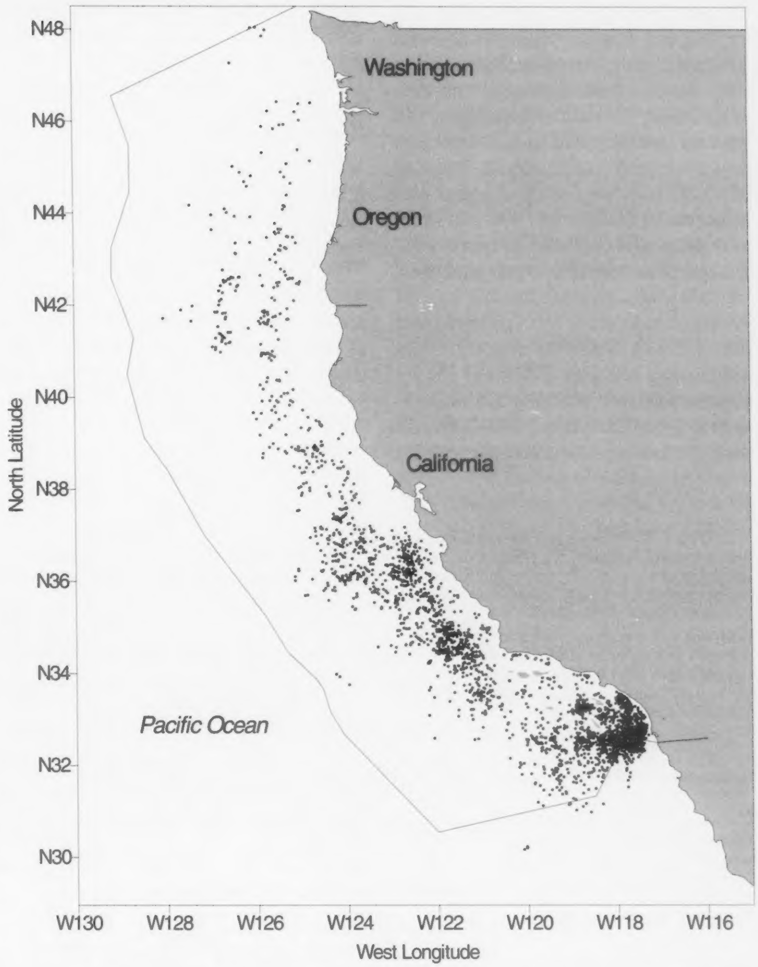


Figure 2.—Locations of 3,369 observed sets in the California drift gillnet fishery for thresher shark and swordfish, 1996–2002.

Effort Estimation

Effort was measured in "effort days" which is defined as one day of fishing effort for one vessel. In the drift gillnet fishery, one effort day is equivalent to the setting and retrieving of one net, which is typically fished for 12–14 h. Fishing effort is estimated by the California Department of Fish and Game (CDFG), based on a combination of observer records, logbook data, and landing receipts. Total fishing effort may be underestimated for two reasons. First, unobserved effort may not be recorded, especially for trips where no marketable target fish are caught and logbook entries are not made. Second, where no logbook or observer records correspond to a landing receipt, estimated effort is based on an assumption that one landing receipt corresponds to one day of fishing effort, when in fact, there may be several days of fishing associated with a given landing receipt. Correcting for this bias is not practical, as the number of days fished per vessel trip varies from 1 to 18 days in this fishery (the average trip length was 5.8 days during 1996 to 2002). It is also unlikely that catch data from landing receipts can be effectively modeled to provide a measure of fishing effort, as the catch per unit effort (CPUE) of target species is highly variable by trip. For these reasons, the total fishing effort and estimated mortality levels reported in this paper are underestimated by an unknown amount.

Mortality Estimation

Ratio estimators were used to estimate mortality with vessel trips as the sampling unit and the number of days per trip as an auxiliary variable (Julian and Beeson, 1998). No geographic or season-

[2]Code of Federal Regulations 50 CFR part 229.2.

al strata were used to calculate kill rates or estimate mortality. Sample sizes for all species except short-beaked common dolphins and California sea lions were insufficient for such stratification, and previous estimates of annual mortality and associated coefficients of variation (CV) are only negligibly changed with such stratification.[3,4] In 1996 and 1997, sets with and without pingers were analyzed as separate strata and total mortality was estimated as the sum of observed mortalities from pingered sets plus a ratio estimate of mortality from unpingered sets (see "1996–97 Pinger Experiment and Mortality Estimation" section). For the years 1998–2002, all fishing effort was assumed to represent pingered sets, so all sets were analyzed as one stratum. For each species, the annual kill rate ($\hat{r}_{s,y}$) of species s in year y was calculated as:

$$\hat{r}_{s,y} = \frac{\sum_i k_{i,s,y}}{\sum_i d_{i,y}} \tag{1}$$

$k_{i,s,y}$ = the sum of observed mortalities of species s in year y for the i^{th} trip and

$d_{i,y}$ = the number of observed days of fishing effort for the i^{th} trip in year y (equal to number of sets observed).

Annual estimates of mortality ($\hat{m}_y$) and associated variance ($\sigma^2_{m,y}$), were estimated for each species using the following formulae:

$$\hat{m}_y = D_y \hat{r}_{s,y} \tag{2}$$

$$\sigma^2_{m,y} = D_y^2 \sigma^2_{r,y} \tag{3}$$

where D_y = the estimated minimum number of days fished in year y,

$\hat{r}_{s,y}$ = the kill rate estimated in year y, and

$\sigma^2_{r,y}$ = the bootstrap estimate of kill rate variance in year y.

[3]Carretta, J. V. Preliminary estimates of cetacean mortality in California gillnet fisheries for 2001. Unpubl. paper SC/54/SM12 presented to the International Whaling Commission Scientific Committee, April 2002, 22 p.

[4]Carretta, J. V. Preliminary estimates of cetacean mortality in California gillnet fisheries for 2000. Unpubl. paper SC/53/SM9 presented to the International Whaling Commission Scientific Committee, July 2001, 21 p.

Table 1.—Number of drift gillnet sets observed from 1996 to 2002 with and without pingers and estimated number of sets fished.

Year	Observed sets: Pingered	Observed sets: Unpingered	Observed total	Estimated sets fished
1996	146	275	421	3,392
1997	388	304	692	3,039
1998	573	14	587	3,353
1999	524	2	526	2,634
2000	444	0	444	1,936
2001	338	1	339	1,665
2002	360	0	360	1,630
Total	2,773	596	3,369	17,649

Table 2.—Summary of annual fishing effort, observer coverage, and observed and estimated mortality in the California drift gillnet fishery, 1996–2002.

Item	1996			1997			1998		
Estimated days fishing effort	3,392			3,039			3,353		
Number of vessels	123			115			123		
Observed days fishing effort	421			692			587		
Observed trips effort	71			118			104		
Percent Observer coverage (days)	12.4%			22.8%			17.5%		
	Mortality			Mortality			Mortality		
Species	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV
Dall's porpoise	2	25	0.74	4	19	0.74			
Pacific whitesided dolphin	3	25	0.98	3	12	0.75			
Risso's dolphin				3	10	0.95			
Common dolphin (shortbeaked)[1]	28	345	0.20	22	114	0.24	9	51	0.38
Common dolphin (longbeaked)[1]				4	27	0.58			
Northern right whale dolphin	5	25	0.71	5	29	0.46			
Shortfinned pilot whale				1	7	0.96			
Sperm whale[1]	1	1					1	6	0.97
Fin whale									
Minke whale	1	12	1.06						
Gray whale							1	6	0.97
California sea lion	4	37	0.55	37	212	0.34	23	131	0.25
Northern elephant seal	5	37	0.53	8	44	0.37	4	23	0.48
Unidentified pinniped							2	11	0.68
Leatherback turtle	2	25	0.63	2	8	0.85			
Loggerhead turtle[1]				1	7	0.93	2	11	0.72
Northern fulmar[1]									
Unidentified bird				1	1	0.00			
All cetaceans	40	433	0.18	42	218	0.18	11	57	0.36
All pinnipeds	9	74	0.38	45	256	0.29	29	165	0.21
All turtles	2	25	0.63	3	15	0.63	2	11	0.72
All seabirds				1	1	0.00			

[1] Includes one animal that was judged to be seriously injured under NMFS guidelines.

For the years 1998–2002, kill rate variances were estimated using a bootstrap procedure, where one trip (1–18 days) represented the sampling unit. Trips were resampled with replacement until each bootstrap sample contained the same number of trips as the actual observed level of effort. A kill rate was then calculated from each bootstrap sample. This procedure was repeated 1,000 times, from which the bootstrap sample variance (kill rate variance) was calculated. For the years 1996–97, kill rate variances were also estimated with a bootstrap, but the sampling unit was represented by individual sets because within an individual trip, some sets utilized pingers while others did not.

1996–97 Pinger Experiment and Mortality Estimation

An experiment to test the effectiveness of pingers on reducing marine mammal entanglement began in 1996 and continued through 27 October 1997, after which time, pingers became mandatory. The experiment was based on a design where sets were randomly assigned as "pingered" or "control" sets after the vessel captain had chosen a set location (Barlow and Cameron, 2003). During the experiment, 534 of 1,113 observed sets (48%) utilized pingers. During the 1997 mandatory period, 214 of 285 observed sets (75%) utilized pingers, and compliance rapidly increased to 90% pinger use in observed sets by December 1997. From 1998–2002, greater than 99% of all observed sets utilized pingers (Table 1).

For 1996 and 1997, mortality estimates were calculated with pingered and unpingered sets/effort representing different strata. In 1996, all pingered sets were observed, so mortality was estimated as the sum of observed mortalities recorded in pingered sets, plus a ratio estimate of mortality from unpingered sets. For 1997, mortality was estimated separately for an experimental period (1 January–27 October) and a mandatory period (28 October–31 December). During the 1997 experimental period, all pingered sets were observed, so mortality was estimated as the sum of observed mortalities recorded in pingered sets, plus a ratio estimate of mortality from unpingered sets. During the 1997 mandatory period, not all pingered sets were observed, so mortality was estimated as the sum of ratio estimates for pingered and unpingered sets.

Estimated effort during the 1997 experimental period was calculated by multiplying estimated 4th quarter fishing effort (2,145 days) by the fraction of observed 4th quarter sets occurring in the experimental period (188/473), plus the sum of fishing effort in calendar quarters 1–3 (894 days). This yielded a total estimate of 1,747 days fished during the experimental period. All pingered sets during the experimental period (n=174) were observed, which leaves $1{,}747 - 174 = 1{,}573$ days of unpingered effort in the experimental period. Estimated fishing effort for the mandatory period was calculated as the estimated 4th quarter fishing effort (2,145 days), times the fraction of observed 4th quarter sets occurring in the mandatory period (285/473). This yielded a total estimate of 1,292 days fished during the mandatory period. Not all pingered sets were observed during the mandatory period, so the total number of pingered sets for the mandatory period was estimated as the number of estimated fishing days for the mandatory period (1,292), times the fraction of observed sets with pingers

1999			2000			2001			2002			1996–2002		
	2,634			1,936			1,665			1,630			17,649	
	96			81			65			56				
	526			444			339			360			3,369	
	92			85			65			64			599	
	20.0%			22.9%			20.4%			22.1%			19.1%	
Mortality			Mortality			Mortality			Mortality			Mortality		
Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV	Obs.	Est.	CV
												[illegible]	44	0.53
			2	9	0.68	2	10	0.71	1	5	0.86	11	61	0.46
			2	9	0.71							5	19	0.60
36	180	0.27	24	105	0.26	7	34	0.41	7	32	0.46	133	861	0.11
1	5	1.05	1	4	1.08				4	18	0.79	10	54	0.41
3	15	0.72	11	48	0.48	5	25	0.57	2	9	0.70	31	151	0.25
												1	7	0.96
												2	7	0.83
1	5	1.05										1	5	1.05
												1	12	1.06
1	5	1.05										2	11	0.71
6	30	0.39	13	57	0.38	2	10	0.67	18	81	0.25	103	553	0.16
2	10	0.65	6	26	0.39	1	5	0.94	1	5	0.92	27	150	0.21
												2	11	0.68
												4	33	0.52
												3	18	0.57
			3	13	0.73							3	13	0.73
									1	5	0.86	2	6	0.72
42	205	0.25	40	175	0.21	14	69	0.31	14	64	0.34	203	1221	0.09
8	40	0.33	19	83	0.29	3	15	0.55	19	86	0.24	132	719	0.13
												7	51	0.39
			3	13	0.73				1	5	0.86	5	19	0.55

during this period (214/285). This yielded a total of 969 pingered effort days for the mandatory period. The number of unpingered effort days in the mandatory period was calculated as the difference between total estimated effort and the estimated number of pingered sets for the period: 1,292 – 969 = 323.

Results

Annual and total estimates of mortality by species, estimated fishing effort, and percent observer coverage for 1996 to 2002 are given in Table 2. Total estimated mortality (CV and observed mortality in parentheses) for 1996 to 2002 is 1,221 (0.09, 203) cetaceans, 719 (0.13, 132) pinnipeds, 51 (0.39, 7) sea turtles, and 19 (0.55, 5) seabirds (Table 2). Observer coverage for 1996 to 2002 was 19% (3,369 days observed out of a total 17,649 estimated days fished, Fig. 2). Annual observer coverage ranged from 12.4% in 1996 to over 22% in 1997, 2000, and 2002. There were 203 individual cetaceans observed killed from 1996 to 2002, comprising 11 species (Fig. 3, 4). Short-beaked common dolphins were the most frequently observed cetacean killed (n=133), followed by northern right whale dolphins (n=31). The 203 cetacean mortalities included three animals (one sperm whale, one short-beaked common dolphin, and one long-beaked common dolphin) that were seriously injured and were likely to result in mortality. Observer notes on the injured sperm whale included observations that the whale rammed the vessel several times hard enough to create deep bleeding wounds on its head. This whale was also released with trailing gear and drifted away from the vessel unable to swim or feed due to the gear entanglement. Observer notes of the injured short-beaked common dolphin indicated that the "dolphin remained motionless and was right-side up at the surface." Observations of the seriously injured long-beaked common dolphin indicated that the animal was "making noises and small movements." This dolphin was released from the net and immediately became entangled again. After a second release, the animal was not seen to surface. Two other long-beaked common dolphins died in this same set. There were 132 pinnipeds observed killed between 1996 and 2002, including 103 California sea lions, 27 northern elephant seals, and 2 unidentified pinnipeds (Fig. 5). The 132 pinniped mortalities included one California sea lion that was seriously injured. Observations of the seriously injured sea lion stated that the animal "displayed some indication of life." The estimate of total loggerhead turtle mortality includes one seriously injured turtle that was released. Observer notes indicated that the "turtle barely moved, even after biopsy was taken." Following release, the turtle moved a little then "sank quickly." The estimate of total northern fulmar mortality includes one bird that was released injured.

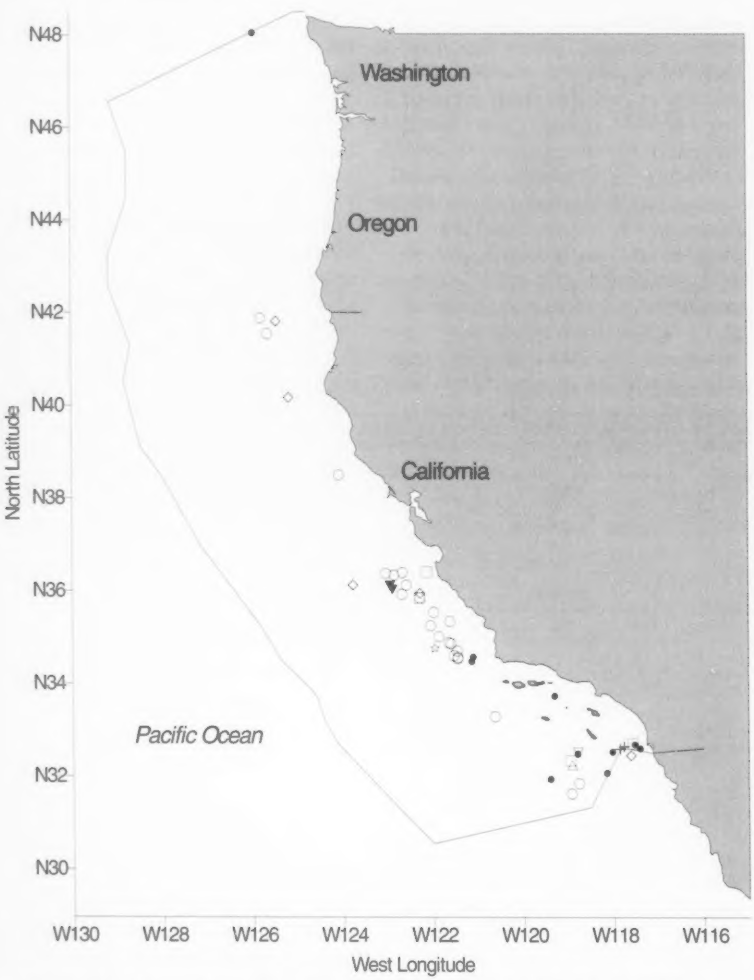


Figure 3.—Observed cetacean kills (other than common dolphins) in the California drift gillnet fishery for swordfish and thresher shark, 1996–2002. Key: ○ = northern right whale dolphin; ● = Pacific white-sided dolphin; ◇ = Dall's porpoise; □ = Risso's dolphin; + = gray whale; △ = minke whale; ▽ = fin whale; ☆= pilot whale; ▼ = sperm whale.

Of the 197 cetacean specimens collected in the fishery from 1996 to 2002, there were 33 where the field identification was changed after a review of genetic and morphological evidence. A

summary of these changes is given in Table 3. Long-beaked common dolphins were the most frequently misidentified species. Of the 13 field identifications of long-beaked common dolphins, nine were genetically identified as short-beaked common dolphins and the remaining four were accurately identified in the field. There were 109 field identifications of short-beaked common dolphins, of which, 104 were correct and five were misidentifications of long-beaked common dolphins. There were 15 specimens where the field identification was either short-beaked common dolphin or long-beaked common dolphin. All were genetically identified as short-beaked common dolphins. Other field identification changes included two unidentified whales that were identified in the laboratory as a minke and fin whale, respectively, one unidentified cetacean identified as a Risso's dolphin, and one unidentified dolphin identified as short-beaked common dolphin.

Discussion

Observed mortality from 1996 to 2002 in the drift gillnet fishery generally reflects species abundance in California waters. Short-beaked common dolphins are the most abundant marine mammal in California waters (>400,000 animals[5]) (Barlow, 1995; Forney et al., 1995), and they were the most frequently (n=133) observed species killed in this fishery. California sea lions are the second most abundant (>200,000) marine mammal in California waters (Carretta et al., 2003) and they were the next most frequently (n=103) observed species killed. Although the Dall's porpoise is abundant in California waters (>90,000 animals[5]), it is infrequently entangled (n=6) because it mainly occurs in northern waters where drift gillnet fishing effort is relatively low. The number of northern right whale dolphins (n= 31) and northern elephant seals (n= 27) observed killed are nearly equal, although the estimated population size of northern elephant seals (100,000 animals, NMFS, unpubl. data, cited in Carretta et al., 2003) is much greater than that of northern right whale dolphins (20,000 animals[5]). Northern elephant seals spend a significant portion of the year feeding north and west of the area where the fishery operates, and they are ashore during their molting period, so it is expected that elephant seal entanglements would be considerably lower based on relative population size.

Mortality estimates in this paper represent minimum estimates, because of negative biases in effort estimation (see "Effort Estimation" section) and because they do not include unobserved mortalities (those occurring in the absence of a fishery observer). Although fishermen are required to report interactions with marine mammals, there is strong evidence that these interactions are grossly underreported. For example, between 1998 and 2002 in the drift gillnet fishery, observers reported 201 marine mammal interactions, with only 20% observer coverage. Over the same time period, all drift gillnet fishermen reported a total

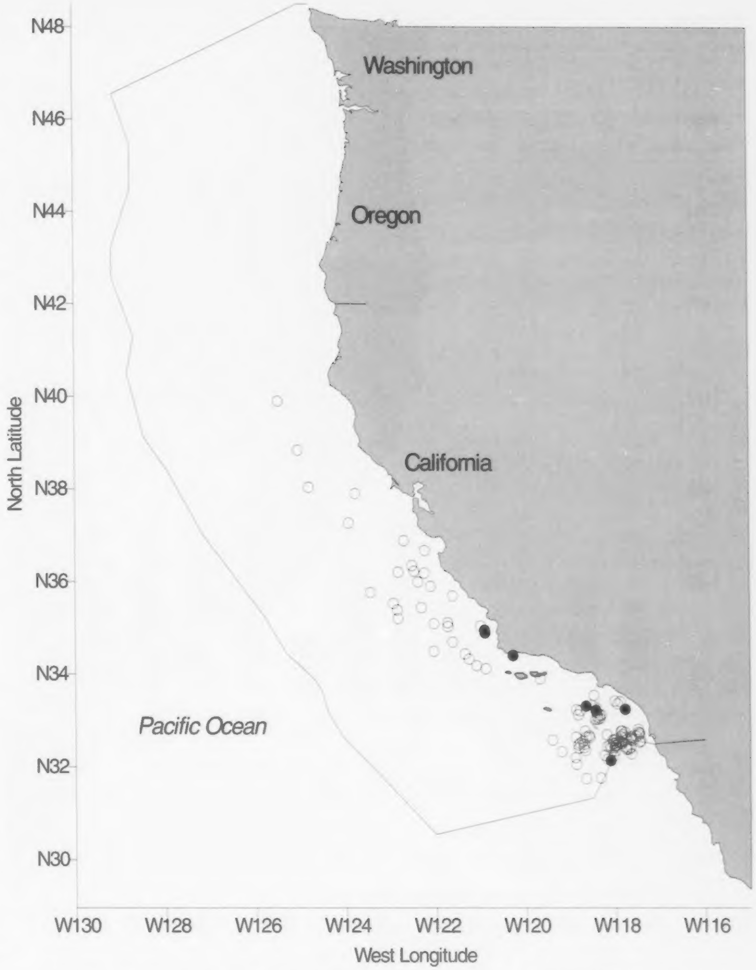


Figure 4.—Observed kills of common dolphin in the California drift gillnet fishery for swordfish and thresher shark, 1996–2002. Key: ○ = short-beaked common dolphin; ● = long-beaked common dolphin.

[5] Barlow, J. 2003. Preliminary estimates of the abundance of cetaceans along the U.S. west coast: 1991–2001. 33 p. Southwest Fisheries Science Center Administrative Report LJ-03-03, available from NMFS Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, 33 p.

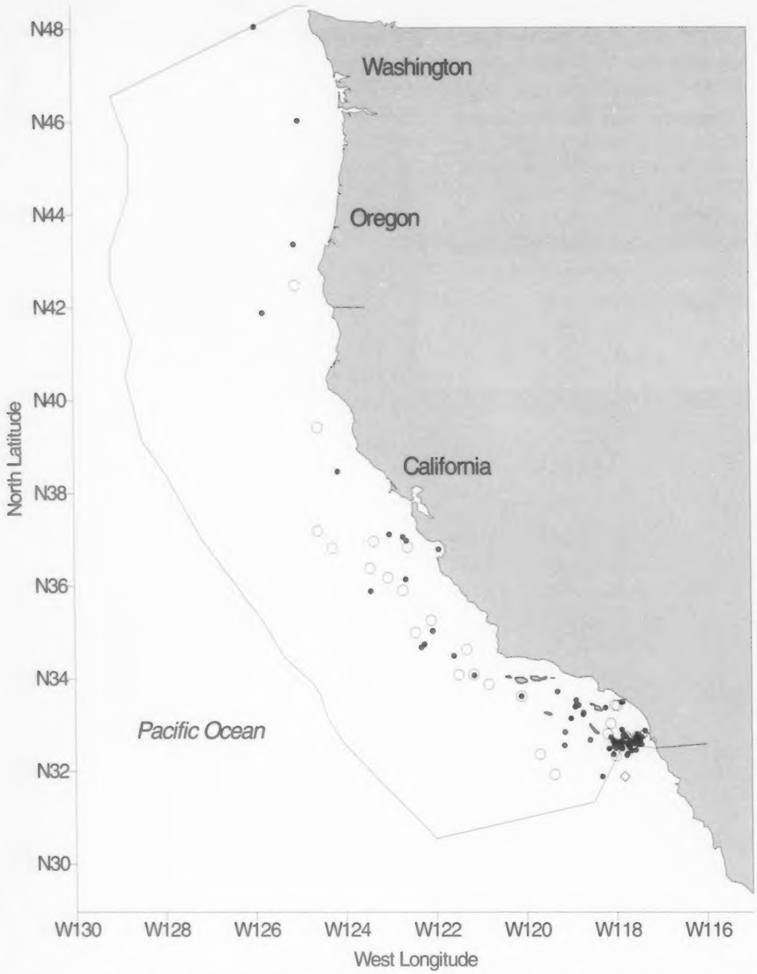


Figure 5.—Observed kills of pinnipeds in the California drift gillnet fishery for swordfish and thresher shark, 1996–2002. Key: ● = California sea lion; ○ = northern elephant seal; and ◇ = unidentified pinniped.

and the fraction of sets fished there has increased because of time/area closures to the north. In 2001 and 2002, the fraction of observed sets south of Point Conception (>85%) was the highest since observations of the fishery began in 1990. However, common dolphin kill rates in 2001–02 were among the lowest recorded for this species since 1990 (Fig. 6). Lack of pinger maintenance may have contributed to high entanglement rates in 1999–2000; observers began checking pinger function once per trip starting in 2001. Variability in annual kill rates for this species is likely influenced by changes in the local distribution and abundance of animals and small-scale changes in the distribution of fishing effort.

Kill rates of California sea lions were significantly lower during the 1996–97 experiment in pingered nets (Barlow and Cameron, 2003). Extremely high kill rates of sea lions in unpingered nets were observed in 1997, during a strong El Niño. In fact, kill rates of sea lions in pingered nets in 1997 were higher than kill rates observed for any previous year (Fig. 7). One possible explanation is that decreased prey availability during El Niño may pressure sea lions into finding alternative food sources, such as stealing fish from commercial nets. This is plausible if, during El Niño conditions, sea lions forage farther from rookeries (Melin, 2002), where they are more likely to interact with the drift gillnet fishery. Sea lion kill rates for the period 1997–2002 were about double of those observed from 1990–96, even though pingers have been required on all sets since late 1997 (Fig. 7).

of 115 interactions where no observers were present (Carretta et al., 2005).

During the 1996–97 pinger experiment, kill rates of short-beaked common dolphins were significantly lower in nets utilizing pingers (Barlow and Cameron, 2003), and the lowest kill rate observed in this fishery occurred in 1998, the first full-year of pinger use (Fig. 6). However, kill rates increased to pre-pinger levels in 1999 and 2000, but have returned to relatively low levels in 2001 and 2002. Reasons for the increase in common dolphin kill rates in 1999 and 2000 are unknown, but a pattern of high kill rates in winter was noted for both years.[6] There were no apparent changes in fishing methodology or location that may have contributed to an increase in common dolphin kill rates in those two years. Common dolphin densities are highest in southern California waters,

[6]Cameron, G. A., and K. A. Forney. 2000. Preliminary estimates of cetacean mortality in California/Oregon gillnet fisheries for 1999. Unpubl. paper SC/52/O24 presented to the International Whaling Commission Scientific Committee, June 2000, 12 p.

There was a noteworthy difference between observed beaked whale mortalities in this fishery from 1990 to 1995 and 1996 to 2002. Julian and Beeson (1998) reported a total of 20 Cuvier's beaked whales, *Ziphius cavirostris*; one Baird's beaked whale, *Berardius bairdii*; one Stegneger's beaked whale, *Mesoplodon stegnegerii*; five Hubb's beaked whales, *Mesoplodon hubbsi*; two unidentified mesoplodont beaked whales, *Mesoplodon* sp.; and three unidentified beaked whales observed killed in this fishery between the years 1990 and 1995. Since

Table 3.—Summary of laboratory vs. field identification of cetaceans incidentally killed in the thresher shark and swordfish drift gillnet fishery, 1996–2002. Summary includes only those 197 specimens for which a tissue sample resides in the SWFSC Genetics Archive. There were an additional four short-beaked common dolphins, one long-beaked common dolphin, and one sperm whale observed killed or seriously injured in the fishery over this period for which no biological samples were collected. The field identification "D spp" denotes an uncertain identification of either short or long-beaked common dolphin.

Laboratory Identification		Field Identification														
Scientific Name	Code	B acu	D cap	D del	D spp	E rob	G gri	G mac	L bor	L obl	P dal	P mac	Unid. cetacean	Unid. dolphin	Unid. whale	Total
Balaenoptera acutorostrata	B acu	1													1	2
Balaenoptera physalus	B phy														1	1
Delphinus capensis	D cap		4	5												9
Delphinus delphis	D del		9	104	15									1		129
Eschrichtius robustus	E rob					2										2
Globicephala macrorhynchus	G mac							1								1
Grampus griseus	G gri						4						1			5
Lagenorhynchus obliquidens	L obl									11						11
Lissodelphis borealis	L bor								30							30
Phocoenoides dalli	P dal										6					6
Physeter macrocephalus	P mac											1				1
Total		1	13	109	15	2	4	1	30	11	6	1	1	1	2	197

that time, no beaked whales have been observed entangled in this fishery. It is unknown whether pinger use has contributed to the decline of beaked whale entanglements since 1996. Barlow[5] noted a decrease in beaked whale abundance from vessel surveys in U.S. west coast waters over the period 1991 to 2001, but it is unclear whether rougher sea states encountered during more recent line-transect vessel surveys has contributed to the apparent decline in beaked whale abundance or whether other factors, such as the susceptibility of beaked whales to anthropogenic noise (Frantzis, 1998; Simmonds and Lopez-Jurado, 1991; U.S. Dep. Commer. and Secretary of the Navy, 2001) might be a factor in their apparent regional decline.

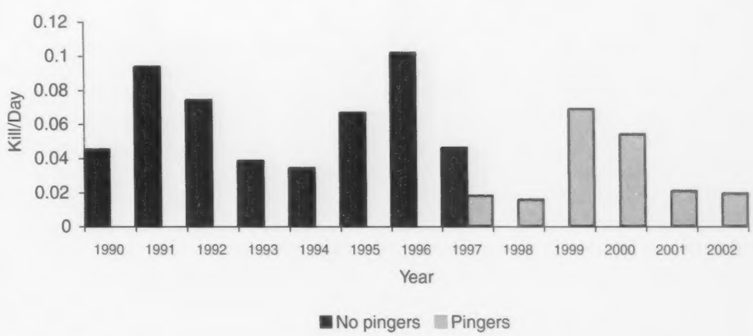


Figure 6.—Kill rates of short-beaked common dolphin per day fished in the California drift gillnet fishery for swordfish and thresher shark, 1990–2002. Kill rates include observations from pingered and unpingered sets. Pingers were not used from 1990 to 1995 and were used experimentally in 1996 and 1997. In 1996, no short-beaked common dolphin were observed killed in 146 pingered sets. For the period 1998 to 2002, over 99% of all observed sets utilized pingers.

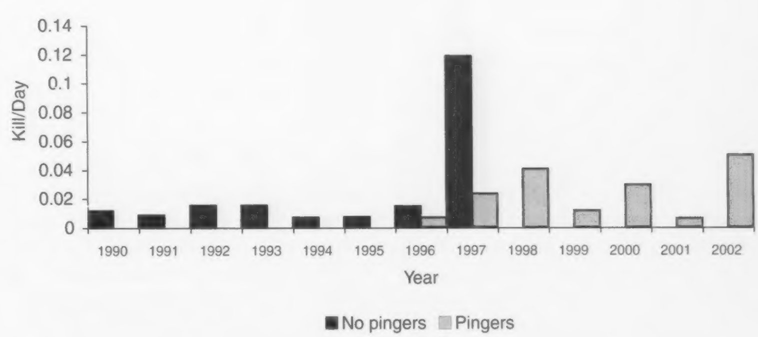


Figure 7.—Kill rates of California sea lions observed in the drift gillnet fishery for 1990 to 2002. Kill rates include observations from pingered and unpingered sets. Pingers were not used from 1990 to 1995 and were used experimentally in 1996 and 1997. For the period 1998 to 2002, over 99% of all observed sets utilized pingers.

Acknowledgments

The data from this fishery are made available through the NMFS Southwest Regional Office observer program in Long Beach, California. This work could not have been done without the hard work and cooperation of the drift gillnet fleet and fishery observers. We thank Lyle Enriquez and Rand Rasmussen for all their efforts in maintaining the observer databases. We thank Jay Barlow, Susan Chivers, Karin Forney, and two anonymous reviewers for their suggestions on improving this paper.

Literature Cited

Angliss, R. P., and D. P. DeMaster. 1998. Differentiating serious and non-serious injury of marine mammals taken incidental to commercial fishing operations: report of the seri-

ous injury workshop 1-2 April 1997, Silver Spring, MD. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-13, 48 p.

Barlow, J. 1995. The abundance of cetaceans in California waters. Part I: Ship surveys in summer and fall of 1991. Fish. Bull. 93:1–14.

________, K. A. Forney, P. S. Hill, R. L. Brownell Jr., J. V. Carretta, D. P. DeMaster, F. Julian, M. S. Lowry, T. Ragen, and R. R. Reeves. 1997. U.S. Pacific Marine Mammal Stock Assessments: 1996. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-248, 223 p.

________ and G. A. Cameron. 2003. Field experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gillnet fishery. Mar. Mammal Sci. 19(2): 265–283.

Carretta, J. V., K. A. Forney, M. M. Muto, J. Barlow, J. Baker, and M. S. Lowry. 2003. U.S. Pacific marine mammal stock assessments: 2003. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-358, 291 p.

________, ________, ________, ________, ________, B. Hanson, and M. S. Lowry. 2005. U.S. Pacific marine mammal stock assessments: 2004. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-375, 316 p.

Chivers, S. J., K. M. Robertson, and M. D. Henshaw. 1997. Composition of the incidental kill of cetaceans in two California gillnet fisheries: 1990–1995. Rep. Int. Whal. Comm. 47:909–915.

Forney, K. A., J. Barlow, and J. V. Carretta. 1995. The abundance of cetaceans in California waters. Part II: Aerial surveys in winter and spring of 1991 and 1992. Fish. Bull. 93:15–26.

Frantzis, A. 1998. Does acoustic testing strand whales? Nature 392:29.

Hanan, D. A., D. B. Holts, and A. L. Coan, Jr. 1993. The California drift gillnet fishery for sharks and swordfish, 1981–82 through 1990–91. Calif. Dep. Fish Game, Fish Bull. 175, 95 p.

Henshaw, M. D., R. G. LeDuc, S. J. Chivers, and A. E. Dizon. 1997. Identifying beaked whales (family Ziphiidae) using mtDNA sequences. Mar. Mammal Sci. 13(3):487–495.

Herrick, S. F. Jr., and D. Hanan. 1988. A review of California entangling net fisheries, 1981–1986. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFC-108, 38 p.

Holts, D. B., A. Julian, O. Sosa-Nishizaki, and N. Bartoo. 1998. Pelagic shark fisheries along the west coast of the United States and Baja California, Mexico. Fish. Res. 39:115–125.

Julian, F., and M. Beeson. 1998. Estimates of marine mammal, turtle, and seabird mortality for two California gillnet fisheries: 1990–1995. Fish. Bull. 96:271–284.

Melin, S. R. 2002. The foraging ecology and reproduction of California sea lion (*Zalophus californianus*). PhD thesis, Univ. Minn., Minneapolis, 150 p.

Simmonds, M. P., and L. F. Lopez-Jurado. 1991. Whales and the military. Nature 51:448.

U.S. Dep. Commer. 1997. Federal Register; Oct. 3, 1997. 62(192):51805–51814.

________ and Secretary of the Navy. 2001. Joint Interim Report, Bahamas Marine Mammal Stranding Event of 15-16 March 2000, 59 p. (Avail. from NOAA, NMFS, Off. Protect. Resour., Silver Spring, MD).

Collaborative Pacific Halibut, *Hippoglossus stenolepis*, Bycatch Control by Canada and the United States

BRUCE M. LEAMAN and GREGG H. WILLIAMS

Introduction

Bycatch of Pacific halibut, *Hippoglossus stenolepis*, in nontarget fisheries has been a major resource removal since the 1960's (Williams et al., 1989). Although targeted by directed commercial setline and recreational fisheries, bycatches of halibut occur in many other fisheries involving various gears. The magnitude of bycatch mortality relative to removals from directed fisheries has caused bycatch to be the subject of much research and management control. The International Pacific Halibut Commission (IPHC), the agency charged through a treaty between Canada and the United States with management of the halibut resource, lacks authority and jurisdiction over nondirected fishing, including bycatch. Thus, management of halibut bycatch falls under the purview of the national governments.

The authors are with the International Pacific Halibut Commission, P.O. Box 95009, Seattle, WA 98145-2009 (e-mail: bruce@iphc.washington.edu). Views or opinions expressed or implied are those of the authors and do not necessarily reflect the position of the National Marine Fisheries Service, NOAA.

ABSTRACT—Bycatch mortality of Pacific halibut, Hippoglossus stenolepis, *in nontarget fisheries is composed primarily of immature fish, and substantial reductions in yield to directed halibut fisheries result from this bycatch. Distant-water bottom-trawl fleets operating off the North American coast, beginning in the mid 1960's, experienced bycatch mortality of over 12,000 t annually. Substantial progress on reducing this bycatch was not achieved until the of extension fisheries jurisdictions by the United States and Canada in 1977. Bycatch began to increase again during the expansion of domestic catching capacity for groundfish, and by the early 1990's it had returned to levels seen during the period of foreign fishing. Collaborative action by Canada and the United States through the International Pacific Halibut Commission has resulted in substantial reductions in bycatch mortality in some areas. Methods of control have operated at global, fleet, and individual vessel levels. We evaluate the hierarchy of effectiveness for these control measures and identify regulatory needs for optimum effects. New monitoring technologies offer the promise of more cost-effective approaches to bycatch reduction.*

Until relatively recently, direct controls over halibut bycatch had been achieved through bilateral agreements enacted by the United States and Canada with other nations. The agreements provided general stipulations for foreign fishing: observers, seasons, closed areas, and limits on the amount of halibut taken as bycatch by each country. International fora, such as the International North Pacific Fisheries Commission (INPFC), served mainly as a venue for discussion and data sharing. Implementation of extended fisheries jurisdiction in the late 1970's passed the development of bycatch controls to agencies of the Canadian and U.S. governments

In this article, we review bycatch of Pacific halibut by nontarget fisheries, the actions that led to the initial international control and resulting measures, the development of bycatch controls by the United States and Canada for their respective fisheries, and the role of the IPHC in discussions between Canada and the United States. We also evaluate approaches and methods to bycatch control and discuss potential future developments.

Bycatch History

Bottom trawl nets were introduced on the Pacific coast of North America in the mid 1910's (Williams et al., 1989). The IPHC prohibited set-nets for halibut in 1938 and the use of any nets in 1944, primarily due to concerns about the harvest of halibut below optimum harvesting size (Hoag, 1971; Skud, 1977). This gear restriction resulted in the retention of trawl caught halibut being prohibited, and the mandatory discarding, with minimal additional injury, of all halibut.

Growth in halibut bycatch followed development of groundfish[1] fisheries, which began in the early 1960's. Up through the 1950's, trawling by U.S. and Canadian vessels for groundfish in the North Pacific was relatively limited. Fishing by vessels from foreign nations, which began in the early 1960's, was more fully developed. Halibut bycatch mortality was relatively small until the 1960's, when it increased rapidly due to distant-water trawl fisheries by Japan, Korea, the U.S.S.R., Poland, and other nations. Total bycatch mortality is estimated to have peaked in 1965 at about 12,800 metric tons (t) (Fig. 1). Bycatch mortality declined during the late 1960's as some of the first bycatch restrictions (e.g. observers and catch accounting) were put into place by the United States, but increased to about 11,900 t in the early 1970's when new areas and species (e.g. walleye pollock) were exploited. During the late 1970's and early 1980's, halibut bycatch dropped to roughly

[1] Primary species included Pacific cod, *Gadus macrocephalus*; rockfishes, *Sebastes* sp.; English sole, *Pleuronectes vetulus;* Dover sole, *Microstomus pacificus;* and petrale sole, *Eopsetta jordani.*

7,100 t, as foreign fishing off Alaska came under increasing control. By 1985, bycatch mortality had declined to 4,600 t, the lowest level since the IPHC began its monitoring nearly 25 years earlier. Bycatch mortality then increased through the late 1980's, due to the growth of the U.S. groundfish fishery off Alaska and the lack of restrictions on that developing fishery. Bycatch mortality peaked at 12,240 t in 1992 but it declined to 7,417 t in 2003. The decline can be attributed to management regulations that encouraged more efficient fishing practices and the introduction of individual quota management programs for the sablefish, *Anoplopoma fimbria*, longline fishery in Alaska and the groundfish bottom trawl fishery in British Columbia.

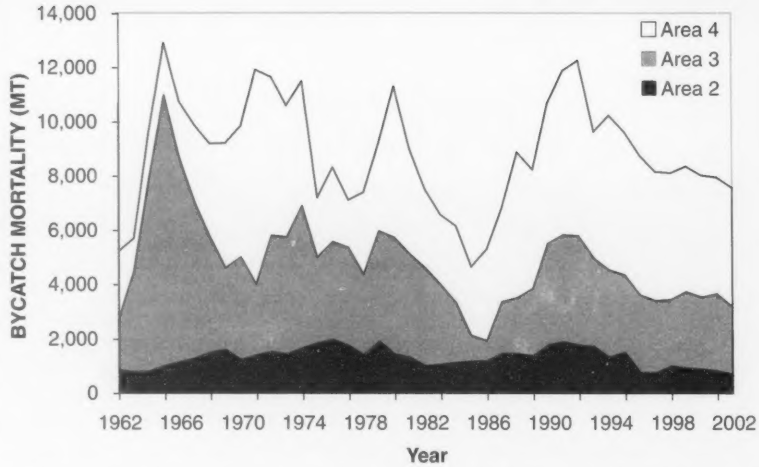


Figure 1.—Historical trend in bycatch mortality of Pacific halibut by IPHC regulatory area, 1962–2002 (Source: Williams, G. H. 2003. Incidental catch and mortality of Pacific halibut, 1962–2002. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 2002:175–186).

International Prohibition

During the late 1960's and early 1970's, regulation of foreign fishing fleets in U.S. waters resulted from bilateral agreements between the United States and the national government of the foreign fleet (e.g. Japan, U.S.S.R., etc.). The agreements identified specific areas and time periods when the foreign fishery was not allowed to operate. This often resulted in a "patchwork" of areas within the Gulf of Alaska and the Bering Sea/Aleutian Islands closed to groundfish fishing at various times of the year. Agreements formulated in the late 1960's were directed at reducing gear conflicts between the North American halibut longline fishery and foreign trawl operations. Typically, foreign trawling was prohibited during the 5–15 day period surrounding the halibut fishery seasons established by IPHC (Fredin[2]). Time/area closures also provided some minor reduction in the halibut bycatch by certain fisheries.

The first direct attempt to control the halibut bycatch in a foreign fishery off Alaska began in 1973, when the IPHC proposed to its member governments that foreign trawling be prohibited in certain areas of the Bering Sea when the incidence of halibut was high (Skud, 1977). Japan responded by voluntarily refraining from trawling in certain areas within the eastern Bering Sea from 1 Dec. 1973 through 31 Nov. 1974. These time/area closures, and similar measures for the Gulf of Alaska, were part of subsequent bilateral agreements between the United States and Japan, the U.S.S.R., the Republic of Korea, and Poland during 1975 and 1976 (Fredin[2]). Figure 2 illustrates the extensive nature of the time/area closures enacted on the Japanese fishery operating off Alaska during that time.

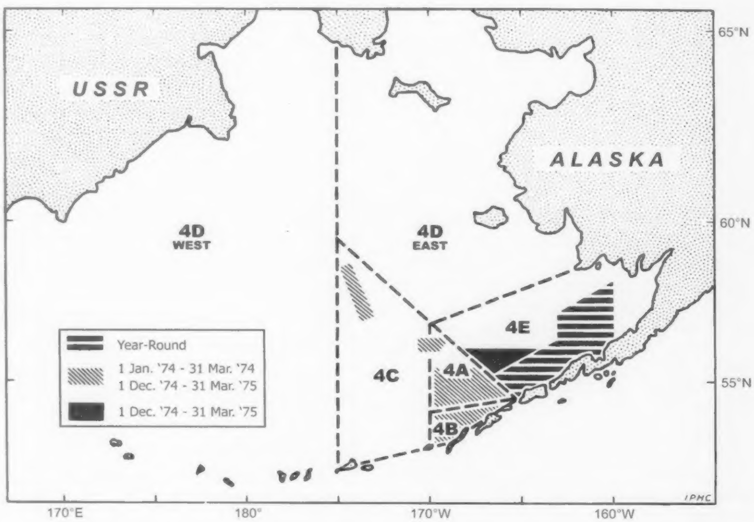


Figure 2.—Areas closed to trawling by Japanese vessels in the eastern Bering Sea during 1 Dec. 1973 to 31 Nov. 1974 (IPHC, 1974: Fig. 2).

[2]Fredin, R. A. 1987. History of regulation of Alaskan groundfish fisheries. NOAA/NMFS/NWAFC Proc. Rep. 87-07, 63 p.

Of relevance is that only time/area closures were used to control halibut bycatch. Bycatch limits were not part of the measures employed, probably because of the lack of a comprehensive observer program that would be needed to monitor compliance. A few observers were placed on foreign vessels as part of a joint program by IPHC, NOAA's National Marine Fisheries Service (NMFS), and INPFC to obtain better information on the magnitude of the halibut bycatch (Hoag and French, 1976), but coverage was limited. Managing bycatch with limits was thought to be impractical at that time.

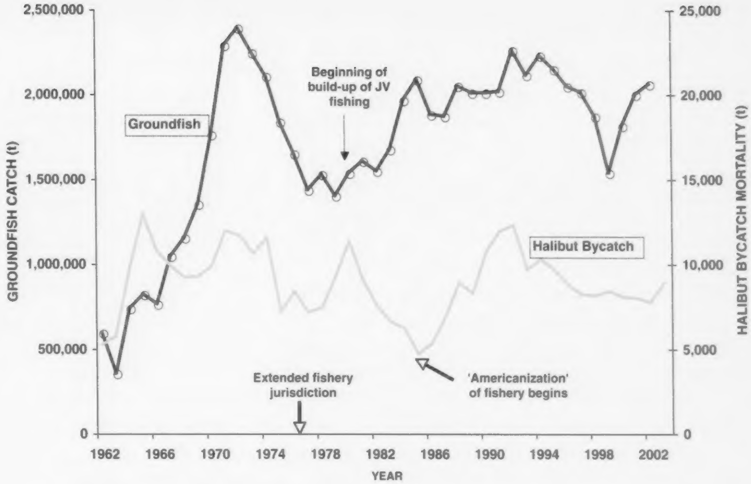


Figure 3.—Groundfish catch and halibut bycatch mortality for Alaska fisheries, 1962–2002 (Source: NPFMC, 2004a, NPFMC 2004b, and Williams, G. H. 2003. Incidental catch and mortality of Pacific halibut, 1962–2002. Int. Pac. Halibut Comm. Rep of Assessment and Research Activities 2002:175–186).

Impacts of Extended Jurisdiction and the Role of the IPHC

The adoption of exclusive economic zones (EEZ) out to 200 n.mi. in 1977 by the United States and Canada mandated the development of fishery management plans that contained many of the bycatch control measures imposed on foreign fisheries. With the exclusion of foreign bottom-trawler fleets from fishing within the EEZ's of the United States and Canada beginning in 1977, the outlook for lower halibut bycatch mortality should have improved substantially. Initially, this proved to be the case as purely foreign fishing was replaced with joint-venture fishing, with domestic catcher vessels delivering to foreign processors (Williams et al., 1989). Observers aboard the joint-venture processors ensured that the restrictions on halibut bycatch mortality that applied previously to foreign catcher vessels also applied during joint venture fishing. By 1985, the halibut bycatch mortality had fallen to 4,644 t from an initial level of over 11,000 t at the beginning of the joint-venture fishing (Fig. 3).

The perception of increased economic opportunity, together with government encouragement, spawned a major initiative on domestic participation in the fisheries formerly dominated by foreign processors. This "Americanization" of the Alaska trawl fisheries began in earnest around 1985, and fully domestic operations quickly became able to harvest the total available catch. This assumption of catching and processing capacity was largely complete by the early 1990's. Domestic harvesters should have been expected to exercise more conservation-oriented harvesting policies concerning halibut bycatch mortality, since the benefits of such policies would accrue directly to the domestic industry. However, controls and monitoring applied to foreign and joint-venture fisheries were not mirrored by similar measures for the newly-domesticated fisheries (Salveson et al., 1992). Bycatch mortality of halibut in domestic fisheries increased steadily from 1985 through 1992, peaking at over 12,000 t (Salveson et al., 1992).

The increasing halibut bycatch mortality and the impact of U.S. halibut bycatch on catch limits for the halibut fishery off Canada led to a confrontation at the 1991 IPHC Annual Meeting between U.S. and Canadian representatives (IPHC, 1992). The high bycatch levels, which were causing decreases in yield to the directed fishery, were of great concern to IPHC. Following much discussion and negotiation, the Commission passed a resolution addressing bycatch mortality (Salveson et al., 1992). Through the resolution, the Commission created a Halibut Bycatch Work Group (HBWG) to review scientific issues and to:

1) Review management measures being implemented in each country to control and reduce bycatch, and advise the Commission on their adequacy,
2) Recommend additional measures which could be taken to reduce bycatch, and
3) Determine appropriate target levels for bycatch mortality reduction.

The recommendations of the HBWG were adopted formally by the two countries in 1991 (IPHC, 1992). Although many recommendations of the group were to the IPHC itself, the major recommendation by the HBWG was for a 10% per year reduction in bycatch mortality off Alaska, beginning in 1993.

Bycatch Control in U.S. and Canadian Domestic Fisheries

The recommendations adopted in the 1991 agreement between Canada and the United States established both reduction milestones and a target for halibut bycatch mortality. Controlling

Table 1.—2002 Pacific halibut prohibited species catch (PSC) limits (t) implemented by the North Pacific Fishery Management Council for Alaska waters. Source: NPFMC (2002a, 2002b).

Area	Trawl PSC	Longline/Pot PSC
Bering Sea/Aleutian Islands	3,675	900
Gulf of Alaska	2,000	300
Total	5,675	1,200

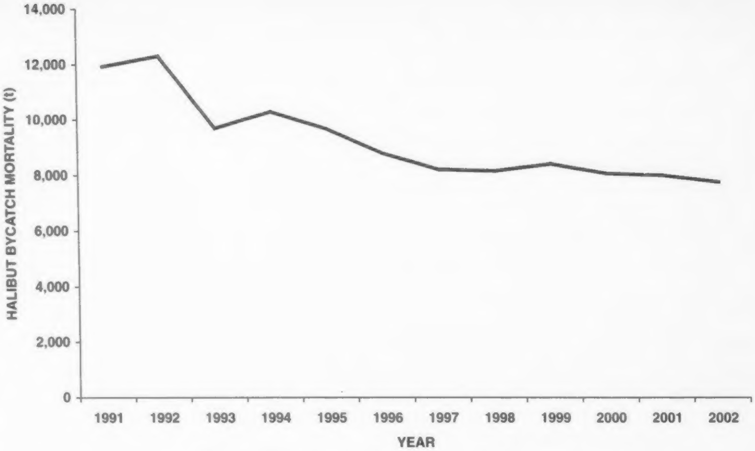


Figure 4.—Halibut bycatch mortality in Alaska trawl fisheries, 1991–2002 (Source: Williams, G. H. 2003. Incidental catch and mortality of Pacific halibut, 1962–2002. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 2002: 175–186).

and reducing halibut bycatch mortality in waters off Alaska is regulated by the North Pacific Fishery Management Council (NPFMC) and similar authority for waters off Canada is vested in the Canadian Department of Fisheries and Oceans (DFO). While both countries implemented a number of similar measures to achieve the bycatch reduction goals, there was a significant difference in one specific measure and the subsequent results achieved.

For Alaska waters, the NPFMC adopted a number of Prohibited Species Catch (PSC) caps for halibut, by target fishery and gear (Table 1). These measures were accompanied by requirements for onboard observer validation, which were scaled to vessel size. Vessels greater than 38 m in length are required to have 100% observer coverage, while vessels between 19.8–38 m in length are required to have observer coverage for 30% of sea days (U.S. Dep. Commer.[3]). Although the IPHC has transmitted the reduction goal and milestones to the NPFMC, the Council has been unable to reconcile this goal completely with its own goals for groundfish fishery development. The NPFMC has also instituted other measures such as careful release programs to reduce discard mortality rates. A vessel incentive program involving penalties for exceeding particular bycatch rates in selected target fisheries was also introduced but was ineffective because vessel crews were able to hide halibut from observers, and the observer catch sampling did not have the statistical properties to allow for prosecution (Renko, 1998). Bycatch mortality declined 17% from 1993 to 2000, as domestic fleets improved gear, employed better release practices when discarding halibut, conducted fishing seasonally to avoid high halibut bycatch, and were managed by bycatch mortality limits (Fig. 4). However, there have been only modest reductions in bycatch mortality in Alaskan fisheries since 2000 (Williams[4]).

For the waters off Canada, the primary source of bycatch mortality is the groundfish bottom-trawl fishery. While the HBWG did not identify specific reduction targets for the Canadian fishery, the DFO began to institute measures to control and reduce bycatch mortality following the 1991 agreement. The most significant measure introduced by the DFO was an Individual Bycatch Quota (IBQ) for each trawl vessel participating in outside water fisheries in 1995. This measure was accompanied by a requirement for 100% observer validation of all trawl hauls and was specific for fishery management areas. If the IBQ for an area was caught, further fishing by that vessel in that area for the remainder of the fishing year was prohibited (Trumble and Leaman[5]). Reduction in halibut bycatch mortality was a remarkable 85% by 1997, and mortality has remained near this level since that time (Fig. 5) (Williams[4]). This reduction was achieved primarily through changes in fishing patterns by time and area, as well as through reductions in fishing effort for some target species, such as Pacific cod, *Gadus macrocephalus*. The effectiveness of the IBQ process is underscored by the fact that vessels consistently catch <60% of their vessel IBQ for a given year (Trumble and Leaman[5]).

Methods of Bycatch Mortality Control: What works?

On an individual vessel basis, the reduction of bycatch mortality can be divided into three major elements: decrease the encounters of the gear and the bycatch species, decrease the retention of encountered fish by the gear, and increase the survival of fish that are retained but subsequently dis-

[3]U.S. Dep. Commer., NOAA, NMFS, Commercial Fishing Regulations, 50 CFR 679.50.

[4]Williams, G. H. 2005. Incidental catch and mortality of Pacific halibut, 1962–2004. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 2005:213–224.

[5]Trumble, R. J., and B. M. Leaman. 1997. Status of 1996 bycatch management planning. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 1996:201–207.

carded. These elements are presented by increasing probability of mortality, so it is clearly desirable to effect bycatch reduction primarily through reduction of encounters between the fishing gear and the bycatch species.

Decreasing Encounters

Decreasing encounters with bycatch species is knowledge-based, i.e. the harvesters must have knowledge of the distribution and/or behavior of the species in order to avoid encounters. This knowledge can be gained through both personal and collective experience. For example, in Alaska this collective experience is employed in a formalized way through a cooperative agreement among some harvesters, conducted by the industry group Groundfish Forum (Gauvin et al., 1996). In the program called Sea State, observers aboard these trawl vessels estimate catch and bycatch. These data are submitted electronically to a centralized repository, where they are checked and extrapolated to include unsampled hauls. Vessel-specific bycatch rates are faxed to participating vessels within 24 h. Similarly, the IPHC has analyzed halibut size frequency data obtained by observers on Bering Sea trawlers to identify areas of consistently high abundance of juvenile size classes of halibut (Adlerstein and Trumble, 1998). These data sources provide knowledge that allows harvesters to avoid areas of high halibut abundance, thereby minimizing the rate at which the PSC caps are approached and allowing greater harvest of the target species.

Knowledge of fish behavior may also allow harvesters to minimize encounters. For example, in the Pacific cod bottom trawl fishery in Alaska, halibut bycatch rates increase nocturnally because the target species (cod) rises off the bottom during darkness. Avoiding fishing during the night can reduce the halibut capture rate relative to the target species. While this knowledge has been useful during parts of the year, a great deal of Pacific cod fishing in this northern area occurs during the winter months, when the hours of darkness are a substantial proportion of the total hours in the day.

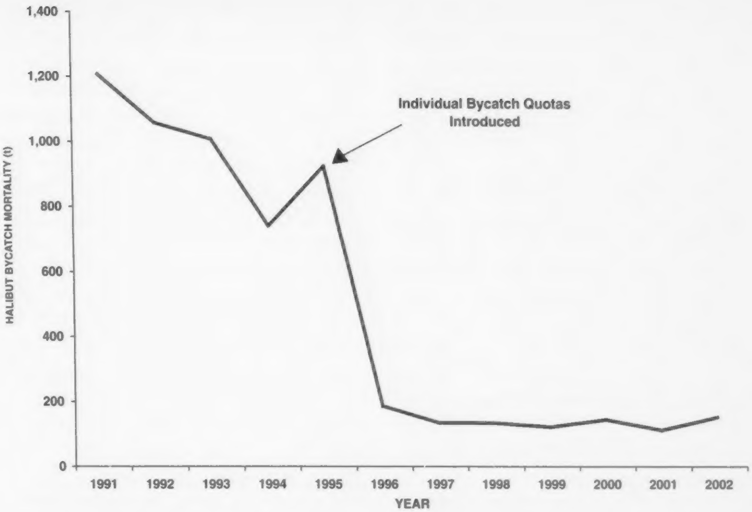


Figure 5.—Halibut bycatch mortality in Canadian trawl fisheries, 1991–2002 (Source: Williams, G. H. 2003. Incidental catch and mortality of Pacific halibut, 1962–2002. Int. Pac. Halibut Comm. Rep. of Assessment and Research Activities 2002:175–186).

Decreasing Retention

Decreasing retention of halibut encountered by the fishing gear has been an area of considerable research. The development of gear modifications to either avoid capture or allow escape of halibut from trawl gear has employed the collective expertise of both harvesters and agency scientists (Rose, 1996; Stone and Bublitz, 1996). In the waters off Alaska, industry groups such as the Groundfish Forum have worked cooperatively with the NMFS to test devices in trawls that allow escape of halibut but retain a large proportion of the groundfish target species catch. Rose and Gauvin (2000) showed that, in tests of flexible halibut excluder panels, only 6% of the halibut were retained while 62% of the aggregate deepwater flatfish[1] were retained. The retention rates for individual flatfish species ranged from 48–79%. This work is especially significant because flatfish-flatfish separation is a far more difficult task than flatfish-roundfish separation. A second significant component of this work is the willingness of the NPFMC to grant an Experimental Fishing Permit (EFP) for the project, allowing cost reduction through retention and sale of the target species by the vessels conducting the experiment (Karp et al., 2001). In the absence of such an EFP, the work would have exceeded both government's and industry's funding ability.

Increasing Survival

If halibut or other bycatch species has been retained by the gear during fishing for other target species, bycatch mortality can still be reduced through increasing the survival of incidentally caught fish. In general, increasing this survival means releasing the fish quickly and carefully. The major issues to be dealt with include either releasing the undesired species before it encounters subsequent damage during the catching or sorting process, or rapidly sorting the bycatch species from the target species to allow subsequent release.

Smith (1996) describes the development and application of three NMFS-mandated methods of careful release of halibut captured incidentally to the Pacific cod longline fishery in Alaska. The three methods—careful shaking, hook straightening, and gangion cutting—all improve halibut survival

compared with the traditional practice of "horning" or "crucifying" the fish (essentially, ripping the hook from the mouth of the fish). The adoption of this careful release program resulted in a 36% reduction in the discard mortality rate for halibut in this fishery (Trumble, 1996). However, a significant feature of measures aimed at increasing survival of discarded halibut is the need for observations on the relative condition of fish, in order to assign a discard mortality rate. Discard mortality rates are calculated from fish condition factors, as assessed by observers using objective criteria, and validated through tag-recovery experiments using the same criteria for assessing the condition of tagged fish at release (Hoag, 1975).

Rapid sorting of halibut from mixed-species groundfish catches can also reduce the discard mortality rate of halibut. Trumble et al. (1995) tested the use of grid sorting grates on groundfish trawlers to speed the extraction of halibut from mixed species catches of roundfish. The grates were highly effective at reducing the time required to return incidentally caught halibut to the sea. Again, the use of this measure requires the presence of observers to monitor the condition of halibut returned to the sea and to validate changes in the discard mortality rate. In the case of factory trawlers, this activity conflicted directly with other priority monitoring and sampling duties of the observers, and the measure was not implemented in the fishery (Trumble et al., 1995).

Hierarchy of Effectiveness

The effectiveness of bycatch mortality reduction measures is also related to the level at which they are applied. A hierarchy of this effectiveness runs from global mortality control, through sector or fleet control, to individual vessel control. Global mortality control is the only option when a regulatory or cooperative framework for more specific control and monitoring does not exist.

For example, restrictions on halibut bycatch mortality in foreign fisheries off the west coast of North America occurred initially at the nation level. That is, each nation participating in the fishery was assigned a total halibut mortality cap, to which it had to adhere. This global level of control was effective primarily because the penalty for noncompliance (exclusion from fishing) was severe and the nations involved exercised control over the individual fishing companies comprising their national fleets. However, the benefits of compliance (access to fishing) accrued at the nation level, rather than at the vessel level.

Sector or fleet level control typifies the present approach to halibut bycatch control in the waters off Alaska. PSC caps are assigned to sectors or fleets that target particular species or species aggregates, e.g. deepwater flatfish, (Dover sole, *Microstomus pacificus*; Greenland turbot, *Reinhardtius hippoglossoides*; and deep-sea sole, *Embassichthys bathybius*), rockfish (*Sebastes* spp.), pollock (*Theragra chalcogramma*), etc. These PSC caps are effective control measures because they limit the activities of these fleets as a function of halibut bycatch. Similar PSC caps exist for other species such as herring, *Clupea pallasii pallasii;* Chinook salmon, *Oncorhynchus tshawytscha;* and red king crab, *Paralithodes camtschaticus*. However, again, the benefits of compliance accrue at the fleet level, rather than at the individual vessel level. Responsibilities and rewards are thus distributed functions.

The final and most effective level of control is demonstrated by the Canadian IBQ experience described previously. These individual controls are applied universally and provide both economic penalties and incentives based on actions by each vessel. The value of individual incentives lies in the direct feedback for vessel bycatch. Compared with the other two levels of control, vessels cannot be penalized and lose economic opportunity through the actions of other vessels.

The Future of Halibut Bycatch Mortality Reduction

Bycatch mortality of Pacific halibut in fisheries off the west coast of North America has not yet achieved the targets agreed upon by the United States and Canada in 1991. However, there has been substantial progress in some areas, including innovative and cooperative research initiatives by industry and fishery management agencies. The future of bycatch control and reduction will be determined by progress on two major issues.

The first issue is the creation of a U.S. regulatory environment that will permit the development of incentives and penalties at the third, or individual, level of control we have described. Achievement of bycatch reduction targets will require translation of policy into economic benefits. These benefits will need to accrue at the level of the individual vessel, since that is the basic level of economic expression for most U.S. fisheries.

In the absence of such a regulatory environment, it is likely that the fishing industry will be required to continue its independent efforts to reduce bycatch and access the additional economic benefits of higher catches of target species. This action will also be necessary to avoid imposition of judicial controls on fishing activities, which are likely to occur as bycatch issues attract greater attention and intervention by nontraditional stakeholders such as environmental groups.

The second issue upon which progress on bycatch reduction may depend concerns the development of new technologies for monitoring the compliance with bycatch control measures. Many measures currently considered require monitoring and validation through at-sea observer programs (ASOP). The average daily cost of an ASOP for each vessel can be US$300–400 or higher if multiple observers are on the vessel. Expansion of bycatch controls into sector, fleets, or vessels not currently covered by ASOP may tax both the capabilities of observer providers, as well as the economic viability of the fisheries.

New technologies, such as digital video cameras linked with geo-positioning, shipboard equipment monitoring software, and tamper-proof installations provide potential for some forms of data acquisition, at substantially lower cost than a traditional ASOP. These new technologies cannot fulfill all functions presently conducted by an ASOP; however, they may provide

a means to focus observer activities on functions that can only be human-based, while other monitoring functions are assumed by technology-based applications. We see this as a major area of development and progress in halibut bycatch reduction.

Literature Cited

Adlerstein, S. A., and R. J. Trumble. 1998. Size-specific dynamics of Pacific halibut: a key to reduce bycatch in the groundfish fisheries. Int. Pac. Halibut Comm. Tech. Rep. 39, 94 p.

Gauvin, J. R., K. Haflinger, and M. Nerini. 1996. Implementation of a voluntary bycatch avoidance program in the flatfish fisheries of the eastern Bering Sea. *In* Solving bycatch: considerations for today and tomorrow, p. 79–86. Alaska Sea Grant Coll. Prog. Rep. 96-03, Univ. Alaska, Fairbanks.

Hoag, S. H. 1971. Effects of domestic trawling on the halibut stocks of British Columbia. Int. Pac. Halibut Comm., Sci. Rep. 53, 18 p.

________ . 1975. Survival of halibut released after capture by trawls. Int. Pac. Halibut Comm. Sci. Rep. 57, 18 p.

________ and R. R. French. 1976. The incidental catch of halibut by foreign trawlers. Int. Pac. Halibut Comm. Sci. Rep. 60, 24 p.

IPHC. 1974. Annual report 1973. Int. Pac. Halibut Comm., Seattle, Wash., 52 p.

________ . 1992. Annual report 1991. Int. Pac. Halibut Comm., Seattle, Wash., 57 p.

Karp, W. A., C. S. Rose, J. R. Gauvin, S. K. Gaichas, M. W. Dorn, and G. D. Stauffer. 2001. Government-industry cooperative fisheries research in the north Pacific under MSFCMA. Mar. Fish. Rev. 63(1):40–46.

North Pacific Fishery Management Council. 2002a. Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region. NPFMC, Anchorage, AK, unpagin.

________ . 2002b. Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. NPFMC, Anchorage, AK, unpagin.

________ . 2004a. Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region. NPFMC, Anchorage, AK, unpagin.

________ . 2004b. Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. NPFMC, Anchorage, AK, unpagin.

Renko, B. L. 1998. Management of Pacific halibut bycatch in the Alaskan groundfish fishery 1990–1996: The vessel incentive program. Master's Thesis, School Mar. Affairs, Univ. Wash., Seattle.

Rose, C. 1996. Behavior of North Pacific groundfish encountering trawls: Applications to reduce bycatch. *In* Solving bycatch: considerations for today and tomorrow, p. 235–242. Alaska Sea Grant Coll. Program Rep. 96-03, Univ. Alaska, Fairbanks.

________ and J. R. Gauvin. 2000. Effectiveness of a rigid grate in excluding Pacific halibut, *Hippoglossus stenolepis*, from groundfish trawls. Mar. Fish. Rev. 62(2):61–66.

Salveson, S., B. M. Leaman, L.-L. Low, and J. C. Rice. 1992. Report of the halibut bycatch work group. Int. Pac. Halibut Comm. Tech. Rep. 25, 29 p.

Skud, B. E. 1977. Regulations of the Pacific halibut fishery, 1924–1976. Int. Pac. Halibut Comm. Tech. Rep. 15, 47 p.

Smith, W. T. 1996. Reduction of halibut bycatch and associated mortality in the Bering Sea cod fishery. *In* Solving bycatch: considerations for today and tomorrow, p. 205–210. Alaska Sea Grant Coll. Prog. Rep. 96-03, Univ. Alaska, Fairbanks.

Stone, M., and C. G. Bublitz. 1996. Cod trawl separator panel: Potential for reducing halibut bycatch. *In* Solving bycatch: considerations for today and tomorrow, p. 71–78. Alaska Sea Grant Coll. Prog. Rep. 96-03, Univ. Alaska, Fairbanks.

Trumble, R. J. 1996. Management of Alaskan longline fisheries to reduce halibut bycatch mortality. *In* Solving bycatch: Considerations for today and tomorrow. Alaska Sea Grant College Prog. Rep. 96-03, Univ. Alaska, Fairbanks.

Trumble, R. J., G. H. Williams, and S. E. Hughes. 1995. Methods to improve survival of Pacific halibut bycatch discarded from a factory trawler. *In* Proceedings of the international symposium on North Pacific flatfish, p. 591–610. Alaska Sea Grant Coll. Prog. Rep. 95-04, Univ. Alaska, Fairbanks.

Williams, G. H., C. C. Schmitt, S. H. Hoag, and J. D. Berger. 1989. Incidental catch and mortality of Pacific halibut, 1962–1989. Int. Pac. Halibut Comm. Tech. Rep. 23, 94 p.

Superintendent of Documents **Subscription** Order Form

Order Processing Code:

***5593**

☐ **YES**, enter my subscription(s) as follows:

____ subscription(s) to the ***Marine Fisheries Review*** (MFR), each at $21.00 U.S. annually

The total cost of my order is $ ________ . Price includes regular shipping and handling and is subject to change. International customers please add 25%.

Company or personal name (Please type or print)

Additional address/attention line

Street address

City, State, Zip code

Daytime phone including area code

Purchase order number (optional)

For privacy protection, check the box below:

☐ Do not make my name available to other mailers

Check method of payment:

☐ Check payable to Superintendent of Documents

☐ GPO Deposit Account

☐ VISA ☐ MasterCard

(expiration date)

Authorizing signature

Mail To: Superintendent of Documents
P.O. Box 371954, Pittsburgh, PA 15250-7954

Submit your order online at: bookstore.gpo.gov

Charge your order. IT'S EASY!

To fax your order (202) 512-2250

To phone your order (866) 512-1800

Thank you for your order!

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.